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VERBATIM TRANSCRIPTS OF THE
PHOTOVOLTAIC APPLICATIONS SEMINAR

OCTOBER 23, 1986

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RESUME

La technologie photovoltaïque joue un rôle croissant dans l'approvisionnement énergétique des collectivités éloignées. Pour les applications industrielles dans le domaine de la télécommunication, le photovoltaïsme peut fournir une part importante d'énergie de façon fiable et économique.

Le 23 octobre 1986, le Ministère fédéral de l'Énergie, des Mines et des Ressources et le Ministère de l'énergie de l'Ontario parainnaient un séminaire sur les applications des techniques photovoltaïques dans le domaine de la télécommunication. Ce séminaire fut donné à l'occasion d'Intelec '86, la huitième conférence internationale de la télécommunication et de l'énergie de l'Institut des ingénieurs électriques et électroniques.

Le séminaire s'adressait surtout aux utilisateurs éventuels, qui ont des factures de consommation d'énergie très élevées, comme ceux qui habitent dans les collectivités éloignées. On s'adressait aussi aux experts de la télécommunication qui tentent de trouver des solutions de remplacement, à ceux qui voudraient augmenter la capacité d'accumulateurs primaires qui alimentent des systèmes photovoltaïques et aux ingénieurs qui cherchent à en connaître davantage sur la technologie.

L'ordre du jour comprenait des questions techniques touchant l'équipement et les procédés, la conception et la gestion de projets, et les sources d'information. On s'est penché sur les systèmes autonomes tandis que les participants d'Intelec s'y sont montrés très intéressés.

Les présentations des douze interlocuteurs ont été reproduites dans le présent document. De plus, les présentations des vendeurs de produits et de services photovoltaïques et de la session des questions ont été incluses.

La plupart des diapositives présentées lors du séminaire ont été annexées à chaque transcription. Celles qui ne sont pas incluses sont mentionnées dans le texte.

L'annexe A présente la bibliographies de chaque interlocuteur. L'annexe B donne les sources d'information et l'annexe C donne la liste de tous les participants au séminaire.

INTRODUCTION

On October 23, 1986, a Photovoltaics Application Seminar was held at Toronto's Royal York Hotel in tandem with the Intelec 86 Conference - the eighth International Telecommunications Energy Conference sponsored by the Communications Society of the Institute of Electrical and Electronic Engineers. The affiliation with this Conference is most appropriate since photovoltaic technology plays an ever increasing role in the provision of dependable, economical, and reliable power for industrial applications for telecommunications in remote areas.

The seminar, sponsored by Energy, Mines and Resources Canada and the Ontario Ministry of Energy, targeted potential users faced with high energy costs, such as those situated in remote communities, telecommunication experts interested in replacing or augmenting primary battery systems powering remote projects with photovoltaic systems and finally, engineers interested in obtaining additional information on photovoltaic technology.

The presentations centered largely on technical issues related to equipment, design basics, project implementation and on information sources. The subject of standalone systems was discussed in length in view of the fact that many of the participants from the INTELEC 86 conference had a vested interest in this area.

A total of twelve presentations were given, each of which have been transcribed verbatim in this report. As well, a group of selected vendors of photovoltaic products each gave a presentation on their products and services. The seminar concluded with a question and answer session which is also transcribed in this report.

Copies of most of the overheads and graphs have been included with each transcription. Slides have not been added, although reference is made to them by number throughout the text.

Bibliographic information on each speaker is given in Appendix A. Appendix B lists a number of information sources and Appendix C includes a list of all seminar participants.

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HISTORY AND CURRENT TECHNOLOGY STATUS OF PV - DR. RAYE THOMAS

(Dr. Thomas is president of TPK International, an Ottawa based firm manufacturing PV modules and production equipment)

I have been asked to talk about the history of PV and it was also suggested that I talk about the current status of technology. Tomorrow I'm leaving for the European Community Semi-Annual Conference on Photovoltaics. Coming back from that, I'd be able to give you a much better picture of what the technology status is, had we waited for another week. However, let's push ahead and look at some of the areas that are relevant to the current status of photovoltaics.

---SLIDE NO. 1

I'll just give you a brief history of photovoltaics. Photovoltaics, in fact, has been around a long time. It was originally identified in chemical solution but, in 1877, was demonstrated in a semiconductor, selenium. That particular semi-conductor has found use in light meters for photography purposes. It's been around for a good long time. It's being used in many devices.

Nothing really happened in terms of photovoltaics as we currently know it. Photovoltaics is really not just restricted to solar energy, but as we know it today, it has been described as being a solar technology.

In 1954, at Western Electric, particularly, six percent efficient solar cells were demonstrated both in silicon and cadmium sulfide. There was a lot of hype surrounding it, a lot of enthusiasm, and in fact, Western Electric licensed a couple of companies to actually manufacture for the consumer market. Now, obviously, they were priced out of the market and the companies died fairly rapidly.

---SLIDE NO. 2

However, photovoltaics didn't die because the space industry came along in about 1958. At that point, we had silicon and cadmium sulfide solar cells available. The silicon solar cell won out in eight to ten percent efficiency range and flew in the first satellite. Cadmium sulfide, in effect, was dead at that point, but

as far as research and development was concerned, a good many people wasted a lot of time and money for the next twenty years or more working on that technology and finally recognized that cadmium sulfide by itself will not make it as a technology.

---SLIDE NO. 3

1973 led to a rebirth in terms of terrestrial applications and also consumer applications because the energy crisis came along. We were looking for ways of actually using the sun. The solar cell was identified as a technology. The solarcell had come along quite a ways in terms of efficiency for space applications, and we're looking at terrestrial applications at that point of perhaps about eleven percent efficiency.

During the intervening period, a lot of research was done, and the terrestrial market came to dominate the industry with the development, largely, of crystalline technology, first of all, for large-area applications, for places where the stand-alone systems --you can leave the system and not worry about it.

In manufacturing, the efficiencies have gone in the range of eleven to fifteen percent on a standard basis. The record now for efficiency with photo cells stands at twenty-odd percent but not really a manufacturable device.

The second technology that's come along is the thin film technology, with the leading candidate being the amorphous silicon solar cell. We see that in consumer applications but not yet in the large-area market, large stand-alone types of applications, because the technology is still unstable.

In the large view, of course, to be cost-effective, you have to have higher efficiencies. If you make high efficiency, you find it degrades fairly rapidly, so there's a lot of work to be done in that particular area as yet.

---SLIDE NO. 4

The key driving force for photovoltaics is obviously cost. Over the years, you can see what happened as we gained experience in terms of the cost of a solar cell

module.

You see, during the space era up to 1973, a gradual increase in cost. Then we artificially forced the development of terrestrial cells, and you have a very sudden drop in terms of the cost and then a more gradual decrease in terms of the cost as we've gone to over over a hundred megawatts of solar cells installed around the world.

There were, of course, projections which were much more optimistic than this. If you look at this particular curve, the bottom curve, it's the sort of projection made by the U.S. Department of Energy. A bunch of guys sitting around having coffee decided to look ahead and see what should happen to solar cell prices and came up with that curve. That's how it developed, and then everybody tried to force the actual cost to that curve.

You see the bulk purchases that the U.S. did here forced the cost down, but realistically, the average price has gone at a higher rate, so that, when we look at projections as to when it becomes really cost-effective for large-area applications in urban environments, we're a long way from that at the moment. We're going up towards 1991 rather than the 1985-86, which was the projected date for it to become roughly competitive in prices. That's U.S. dollars.

---SLIDE NO. 5

Now, some of these slides don't really make too much sense. Most of you know about photovoltaic conductors already, but let's look at photovoltaic devices. They're basically a device which converts the energy in radiation to electrical energy, a direct conversion technique.

The essential feature that you need in the device in order to do that is a material that has the ability to absorb the photons of light, transmitting their energy through the atoms in the material itself, thereby creating a charge, and then the ability to separate that charge. We have to have a built-in electrical field somewhere in the device.

---SLIDE NO. 6

We look at the solar cell and all it really is, is a glorified diode. There may be different ways of making that diode, but if we look at this simplified picture, which is the crystalline solar cell, we have a material, silicon typically, as a bulk material. We diffuse in the phosphorus to create an N-type region, and you've got an N-P diode. You make a grid contact on the top surface and a whole contact on the back surface.

The sunlight can shine in between the grid fingers and be absorbed in the material. At the junction, you have a built-in electrical field, and that electrical field can separate the charge, providing the charge that's being generated herein the bulk material can find its way to that charge release. You separate the charge. It gives you a voltage. On the external surface, a current will flow.

That's all that this photovoltaic device is, but the whole thing in terms of making that device has been the technology to allow you to make a highly efficient device, a large-area device, and a low-cost device. That's what has driven -- the cost, primarily -- has driven the development of the solar film.

---SLIDE NO. 7

If we look at some of the things that add to cost -- and this is rather cluttered. Ignore everything over on the right-hand side. In fact, I'll cover it up so you don't have to worry about it. The typical approach has been silicon, as the one material that, it is well known, has a lot of history in the development of the integrated circuit industry.

You're starting with quartz and coke. You do a carbon arc reduction in the furnace, producing metallurgical-grade silicon, which is about ninety-eight, ninety-nine percent pure.

That's not good enough to make a high-efficiency device, so you've got to go through a purification step. You convert it to a liquid phase and then a gaseous phase where you now have the high-purity material, and then you deposit it on some seed material, giving you a polycrystalline semiconductor. That's the traditional

approach for making silicon for integrated circuits or for solar cells.

A lot of energy costs, so you look for ways of getting around it. These just represent some of the research paths that have been followed: purer starting material, fewer steps in the process. Those are not relevant yet because they have not been developed to the stage where they could be used in making that material.

---SLIDE NO. 8

Having gotten the polycrystalline silicon, now you have the various routes to making the material that can be used to make solar cells. The conventional approach is the Czochralski technique where you dip the seed into the molten silicon: melt the polycrystalline material down, dip the seed in, pull it out into an ingot, and then saw it up into slices.

The second approach for polycrystalline material: Polycrystalline simply has more than one grain in the material. You can cast it. Here, you pull a circular ingot. This one, you can cast into a square ingot, so you have; in terms of ultimately making a photovoltaic module, something that has better packing density in the module, better use of space; but in the polycrystalline material, of course, the grain boundaries between the crystals reduce the efficiency of the solar cell. You don't quite get the same result. There's a trade-off involved.

Techniques used by Wacker in Germany is the Silco technique. Semix is a Solarex process, and those are in production at the moment.

Another technique is the heat exchange method, which gives better results in terms of material, but it's not really in full production. We still have to go through a length of time on that one.

Then there's a lot of hype about actually dipping the seed in the melt and pulling a ribbon. We've got, probably, a list of techniques. They all go by initials, but it's about twice as long as that particular list. Many of them will never see the light of day because they cannot lend themselves to volume production.

The two that have possibilities and are in limited production are the EFG technique, which is in production for making solar cells in the States, and the Webb technique, which was developed by Westinghouse. It gives you good polycrystalline material and can give you very good results, comparable with single-crystal material.

---SLIDE NO. 9

Here's the melting down of the silicon, and you'll see the seed's dipped into the silicon on the top. You rotate it, pull it gradually, and you start freezing out the molten silicon onto that seed; and then, as you pull it further, you control the diameter, so you get an ingot which is a single-crystal, long ingot, controlled diameter, and then you can use that in your production.

---SLIDE NO. 10

For example, here's finishing off the process where you're melting down. You're freezing out the last of the material -- and an ingot. That's a particularly short one that we grew during this last year, but you can grow them up to several feet long and about five or six inches in diameter.

In the integrated-circuit industry, you use, typically, a six-inch diameter. For the solar industry, you can either do a hundred-millimetre diameter, four inches in diameter, and use that as a circular solar cell, or you grow it five inches in diameter and you cut it into a pseudo-square geometry, which gives you a better packing density. The material you cut off, you throw back into the next melt and reuse.

---SLIDE NO. 11

Now, having once gotten your silicon material, you go through a process of making the solar cell. There are different ways of making that solar cell, but this is a typical type of approach. This is one we ourselves use and have sold to customers in India and China.

Now, if you look at silicon, as you see, for an integrated circuit, it has a tremendous amount of reflectivity, so you have to make certain that you do not reflect from that surface. The step here is one where you actually etch it with a crystal graphic edge, create

pyramids, so that the reflection from the side of the pyramids into the material -- you don't have a reflection back out of the silicon. That is done in that process. The saw damage is sliced in wafers from the ingots, so you remove the saw damage in that particular case. You use a similar sort of approach for polycrystalline materials to prepare the surface as well.

You then go through a junction diffusion process. That particular one shown is very similar to what's used in the integrated circuit industry, the same sort of equipment; or you can use a melt-furnace, which is used by many people. You create a junction around the material both in the front and the back, separated at the edges; and now the contacting process, which lends itself to large-scale automation and has been one of the factors in bringing down costs: You screen-print contacts on a silver grid on the front, silver and aluminum on the back, and that gives you a very efficient solar cell and good contacting technique.

You can further reduce reflection by putting in a coating. You put an optical coating material on the surface. Titanium dioxide, for example, will give you better matching on the surface and reduce reflection still further, so you can get the reflection down to, perhaps, three percent in the best type of solar cells you can get.

Then you test them and sort them into categories because you'll have a distribution in the yield of solar cells, so you sort them into categories where the current is very well matched before you put them into modules later on.

---SLIDE NO. 13

Now, I'll leave some of the views of the equipment out which I've brought along. In the end, you might end up with solar cells which look like that. Those are four-inch diameter solar cells with the grid. Many contact points are put on the solar cells, so when you interconnect the solar cells in a series string, you have a lot of redundancy built in, so if you broke the solar cell at one point, you should not lose more than ten percent of the power from that solar cell.

There's a flat that you see on the edges of the solar

cell. That's simply for automation purposes so you can actually identify the orientation of the material for automatic handling of the solar cell.

The difference between the single-crystal solar cell and the polycrystalline solar cell is something you see, looking at that particular version. You see all the different grains of material that are in that polycrystalline solar cell. These grains must be larger than half a millimetre in order to give you reasonable efficiency in the order of ten percent on the solar cell. In fact, you'll find with some that they are over an inch in size. That would be a four-inch by four-inch solar cell.

---SLIDE NO. 14

Now, I mentioned that we had made a lot of progress in solar cells. Typical manufacture is in the region of 12 1/2 percent average, but here is what's happening as far as the development of the solar cell is concerned.

These are results that were reported in the fall of '85, and we've gone further than that, particularly in this group at the University of New South Wales, Martin Green, who, in fact, did his education at McMaster University.

You can see that the factors that you identify in terms of a photovoltaic module are the short-circuit current: How high can you get the short-circuit current in terms of current density? Typically, theoretical measurements for air mass one -- that is, no concentration of sunlight -- is about the order of forty milliamps per square centimetre, so we're getting up there on these particular devices.

The open-circuit voltage is typically just over about two-thirds of the energy band gap of the material, so in terms of silicon, you should be able to get maybe two-thirds of 1.1 volts, so here, we're over six hundred millivolts at that particular point, so that's been pushed up quite well.

The fill factor, the theoretical limit is about .83 or .84, as you see, in these devices. The fill factor simply says what is the maximum power rectangle you can get in the current voltage characteristic of the solar cell.

---SLIDE NO. 15

Finally, efficiency is over twenty percent now. These ones that are shown are up to 19.8. The record has been pushed above that very recently.

---SLIDE NO. 16

The modules: once you've got your solar cells connected in series, about thirty-six of them typically could give you the voltage needed to charge a twelve-volt battery. The current technology is tempered low-iron glass as the front material, ethylene vinyl acetate, which is a thermostatic plastic material, surrounding the cell protecting its environment, the cell in the middle of that material, and then a backing material of Tedlar, typically, or a laminate of Tedlar on the back.

Modules done in this way have been tested to give you a lifetime on the order of twenty-five years, and I think we're shooting for thirty years. In fact, if you look at the guarantees on the modules, you will find they are creeping up to the ten-year category. That's no more than ten percent degradation in that period of time.

This technology, we're very much into. We make equipment to do the lamination of those modules.

---SLIDE NO. 17

Now, the other technology that's come along -- as I mentioned, I'm going to talk more about that later this afternoon -- is the amorphous silicon technology.

This gives you an idea of what is happening as far as the photovoltaics industry is concerned. These are the top ten producers in 1985 around the world. Canada doesn't show anywhere on any chart in the top fifty, I don't think.

The single-crystal technology had about 10.9 megawatts last year; multi-crystalline technology, about five megawatts; and about 8 1/2 megawatts for amorphous silicon. That's the thin-film technology that's coming on. You find at this point that it's low efficiency, but if its efficiency could be pushed up, the cost would be dramatically reduced and it would take over a fair

percentage of the market.

There are reasons for going to that. I think I'll leave that till this afternoon, but I'll give you just a comparison of the technologies at this particular point in time.

---SLIDE NO. 18

They are all silicon-based solar cells. Now, there are a couple of other technologies I'll mention this afternoon. They're nowhere yet in terms of being available.

The single-crystal silicon, typically 12 1/2 percent efficiency in production; where you get, with the polycrystalline material, typically, a lower percentage. Maybe 10 1/2 to 11 1/2 would be probably more correct for efficiency on that particular material. Ribbons give you about 11 percent; amorphous silicon that's reported in terms of production, around six percent at this stage.

Module efficiency: Of course, you lose something in putting the cell into the module, and there's some wasted space, so it makes the efficiency lower, but the packing density for the polycrystalline material is very good, so we don't lose much.

---SLIDE NO. 19

Manufacturing costs are comparable. Even though the projections are that some technologies are going much cheaper than others, they're not, at this point. Profitability price: You can see roughly where we are at the moment. In fact, I would suggest the profitability price is probably higher because I don't know of any of the major manufacturers on that list that I showed earlier that are making a profit.

---SLIDE NO. 20

Finally, I'll give you a summary of this section. This is where we are in Canada. As I said, we're not very far along. The only solar cells made in Canada, to my knowledge, are single-crystal silicon ones. They're made by TPK and Silonex in Montreal. In fact, the bulk of the solar cells are imported.

Polycrystalline silicon: There is no Canadian

manufacturer. We import the cells in modules, generally, but Bestek can make small modules out of imported solar cells.

Amorphous silicon is in the research stage. The other technologies are ones I'll mention this afternoon, but they're really in the research stage in Canada. There's nothing available in terms of the market.

Modules are made in Canada, typically, by TPK, Silonex, Bestek, and Solarpac. I believe those are the manufacturers but in small quantities, as I say. The market has not developed sufficiently. I'll stop there.

BRIEF HISTORY OF PHOTOVOLTAICS

- 1877 - PV EFFECT DEMONSTRATED IN SELENIUM
 - USED IN LIGHT METERS FOR PHOTOGRAPHY
- 1954 - 6% EFFICIENT SOLAR CELLS IN SILICON AND CADMIUM SULPHIDE
 - WESTERN ELECTRIC LICENSED TWO MANUFACTURERS AIMED AT CONSUMER MARKET. TOO EARLY - COMPANIES DIED
- 1958 - SILICON CELL FOR SPACE (8 - 10% EFF.)
- 1973 - ENERGY CRISIS - MEANT DEVELOPMENT OF TERRESTRIAL APPLICATION
- 1980 - TERRESTRIAL MARKET DOMINATES
 - CRYSTALLINE SILICON FOR LARGE APPLICATION (11 - 15% ; 20% RECORD)
 - AMORPHOUS SILICON FOR CONSUMERS 4 - 6%

SLIDE NUMBER 1

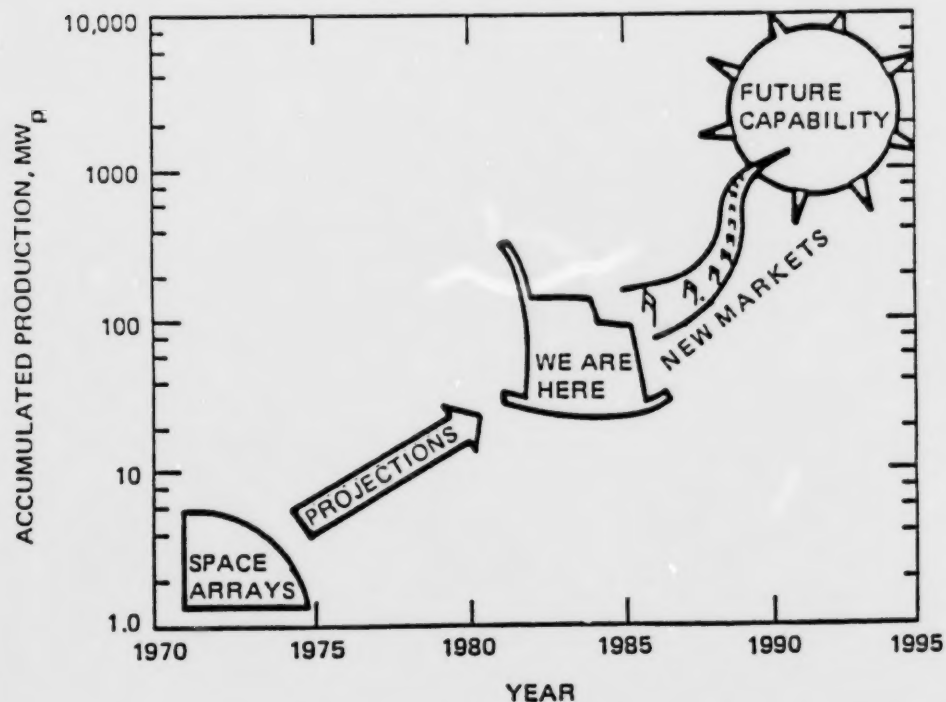


FIGURE 1. SOLAR CELL MODULE ACCUMULATED PRODUCTION - PAST AND FUTURE

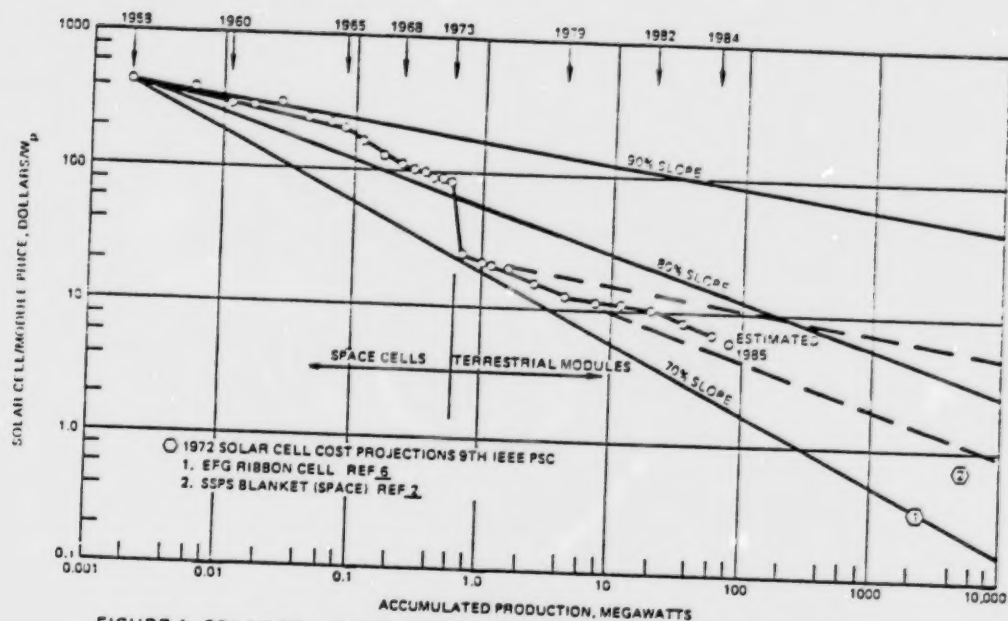


FIGURE 4. SOLAR CELL/MODULE PRICE AS FUNCTION OF PRODUCTION EXPERIENCE

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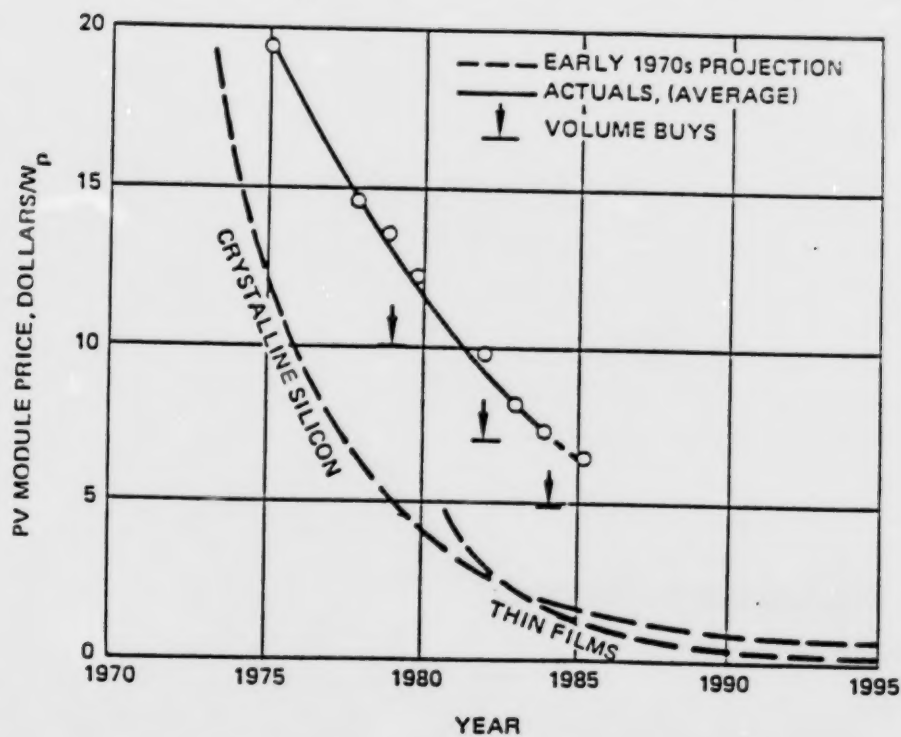


FIGURE 5. MODULE PRICE CURVE -ACTUALS VERSUS PROJECTIONS

SLIDE NUMBER 4

WHAT IS THE PHOTOVOLTAIC EFFECT?

THE GENERATION OF ELECTRICAL ENERGY AS A
CONSEQUENCE OF ABSORPTION OF IONIZING RADIATION
(E.G. LIGHT). (DEMONSTRATED 1877 IN SELENIUM.)

WHAT ARE PHOTOVOLTAIC DEVICES?

• DEVICES WHICH CONVERT ENERGY IN RADIATION TO
ELECTRICAL ENERGY.

• ESSENTIAL FEATURES ARE:

- ABILITY TO ABSORB LIGHT PHOTONS
- ABILITY TO SEPARATE CHARGE BY A
BUILT-IN ELECTRIC FIELD.

SOLAR CELL HAS THESE FEATURES.

SLIDE NUMBER 5

TPK SOLAR SYSTEMS INC.

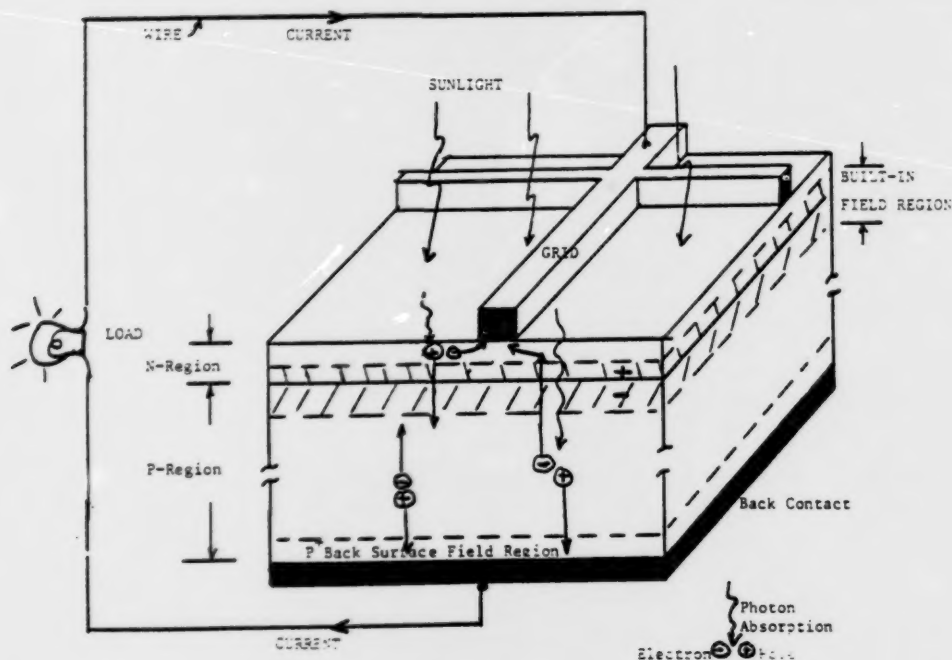
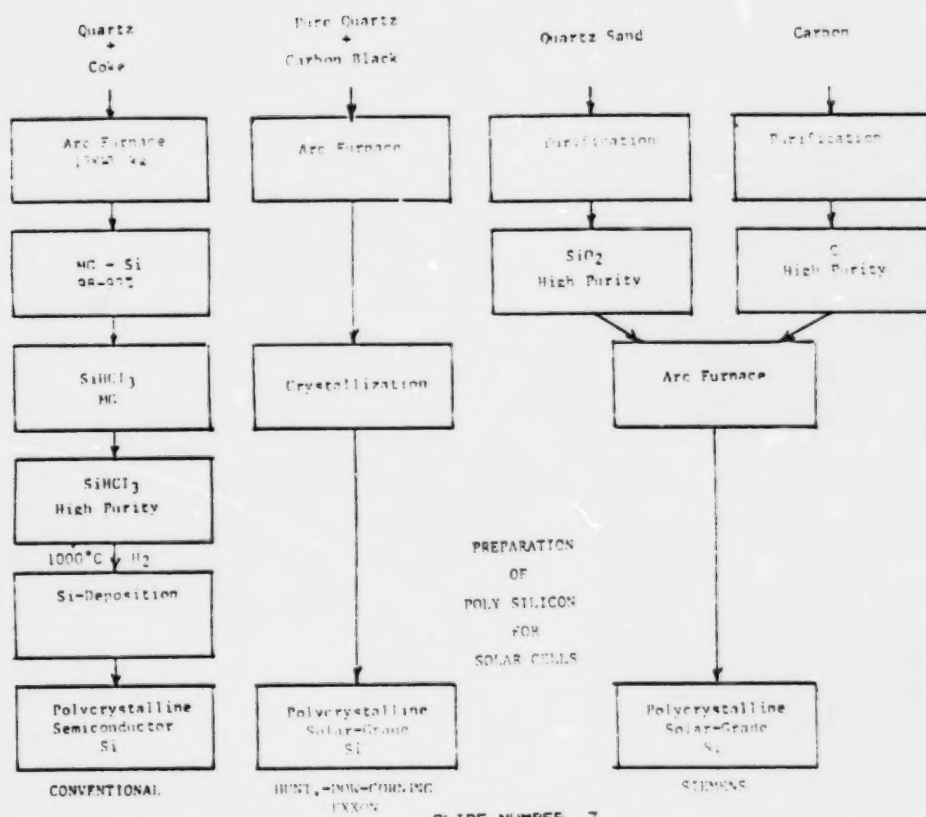


Figure 1. SOLAR CELL OPERATION

SLIDE NUMBER 6



SLIDE NUMBER 7

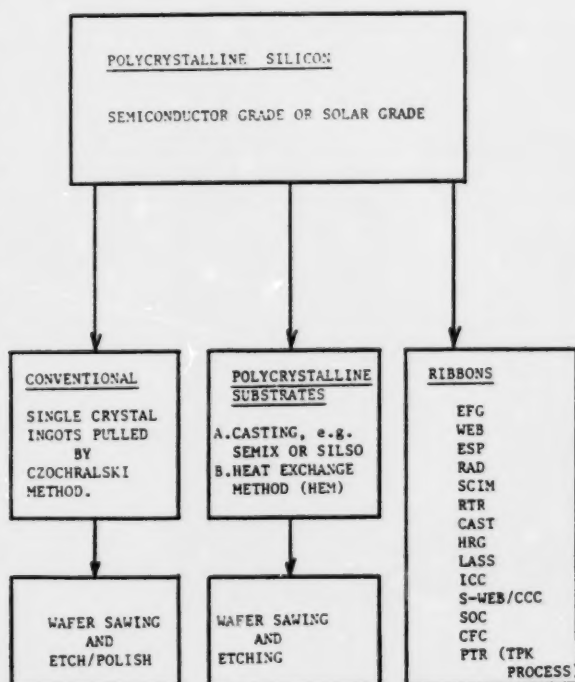


Figure 3. TURNING POLYCRYSTALLINE SILICON INTO USEABLE SUBSTRATES FOR SOLAR CELLS

SLIDE NUMBER 8

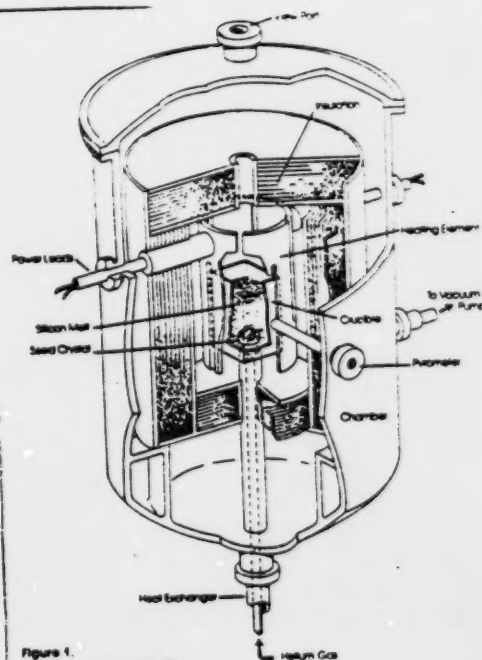


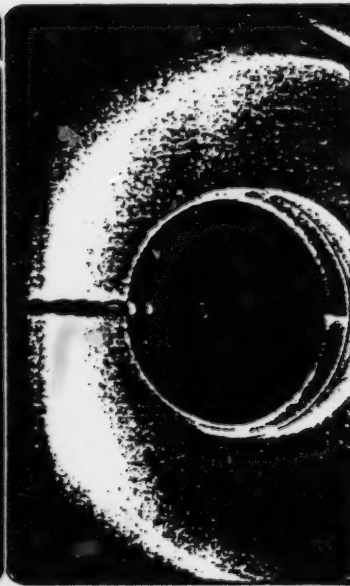
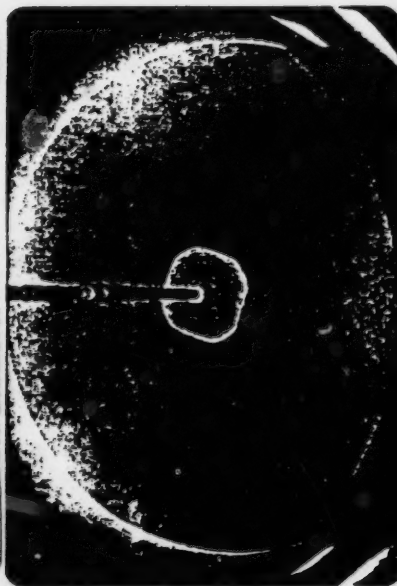
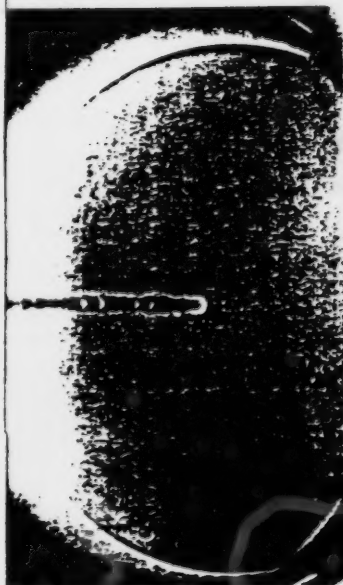
Figure 4. SCHEMATIC OF THE HEM FURNACE

SLIDE NUMBER 8A

Optical Spectra.

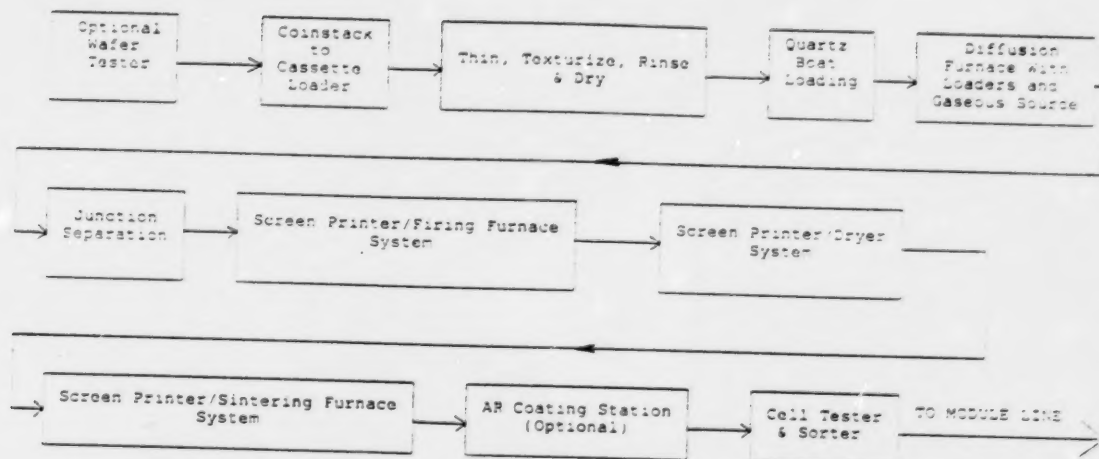


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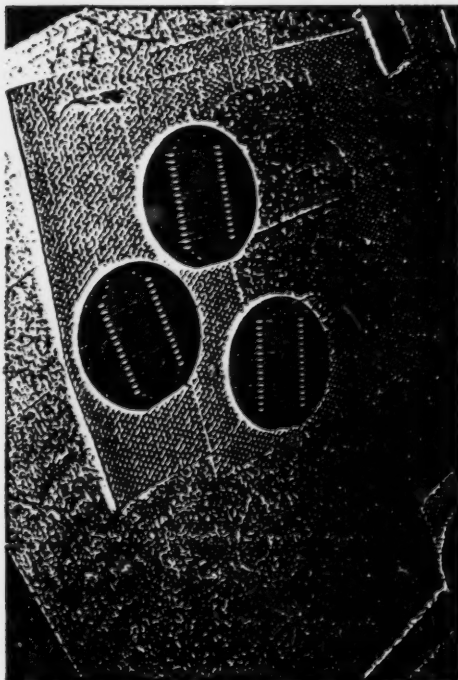
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SOLAR CELL PRODUCTION LINE

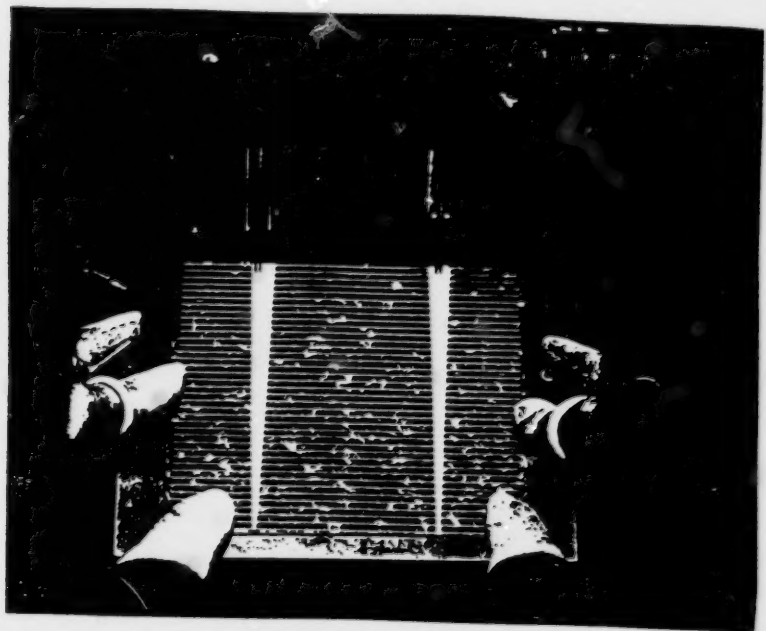


STPK SOLAR SYSTEMS INC.,
Ottawa, Ontario, Canada.
1986

SLIDE NUMBER 11



SLIDE NUMBER 12

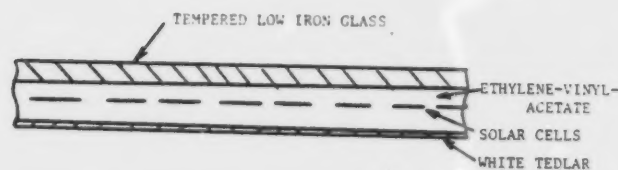


SLIDE NUMBER 14

SOME RECENT HIGH-EFFICIENCY SILICON SOLAR CELLS TESTED UNDER ONE-SUN AM1 ILLUMINATION

J_{sc} mA/cm ²	V_{oc} mV	FF	η %	Substrate Resistivity ohm-cm	Source
36.2	600	.793	17.2	4.0	Westinghouse ²
36.0	627	.800	18.1	0.2	Westinghouse ³
36.1	623	.815	18.3	0.3	Westinghouse ⁴
35.9	627	.800	18.0	0.3	Spire Corporation ⁵
36.2	641	.790	18.3	0.2	Spire Corporation ⁶
33.0	653	.810	17.5	0.3 Concentrator Cell	Sandia National Laboratories ⁷
34.0	624	.820	17.6	0.3 Concentrator Cell	Applied Solar Energy Corporation ⁷
35.1	623	.780	17.1	0.3	Catholic University of Leuven, Belgium ⁸
35.5	641	.822	18.7	0.2	University of New South Wales, Australia ^{9,10,11}
36.0	653	.811	19.1	0.2	
36.5	662	.819	19.8	0.2	

SLIDE NUMBER 15



CROSS-SECTION OF PHOTOVOLTAIC MODULE

SLIDE NUMBER 16

TOP 10 COMPANIES IN PHOTOVOLTAICS - 1985
SHIPMENTS IN MEGAWATTS PEAK

COMPANY	1984	1985			TOTAL
		SINGLE CRYSTAL	MULTI- CRYSTAL	a-Si	
1. ARCO SOLAR, U.S.A.	5.50	4.7	---	0.2	4.9
2. SANYO, JAPAN	3.50	---	---	3.9	3.9
3. FUJI, JAPAN	2.50	---	---	2.8	2.8
4. SOLAREX, U.S.A.	2.10	---	2.0	0.2	2.2
5. PHOTOWATT, FRANCE	0.60	---	1.0	---	1.0
6. SHARP, JAPAN	0.50	0.9	---	---	0.9
7. AEG, WEST GERMANY	0.75	---	0.8	---	0.8
8. KYOCERA, JAPAN	0.65	0.2	0.4	0.1	0.7
9. CEL, INDIA	0.20	0.6	---	---	0.6
10. ECD-SHARP, JAPAN	0.40	---	---	0.5	0.5

WORLD TOTAL

> 30 MW

CANADA TOTAL (RECENT NRC REPORT, 1986)

72.3 KW

SLIDE NUMBER 17 - 20 -

TECHNOLOGY COMPARISON OF SILICON BASED SOLAR CELLS

	<u>SINGLE CRYSTAL</u>	<u>CAST P-C MATERIAL</u>	<u>RIBBON/SHEET</u>	<u>a-Si</u>
CELL EFFICIENCY (%)	12.5	11-12	11	6
MODULE EFFICIENCY (%)	11	11	10	5
WARRANTY (YEAR)	5-10	2-5	2-5	1
MANUFACTURED COST (US\$/Wp)	4.00	2.00-2.50	4.50	3.00-4.00
PROFITABLE PRICE (US\$/Wp)	6.50	3.50-4.00	7.50	5.00-6.50

SLIDE NUMBER 19

SOLAR CELL TECHNOLOGIES IN CANADA

SINGLE CRYSTAL SILICON	* CELLS MADE BY TPK (100mm diameter) AND SILONEX. BULK IMPORTED.
POLYCRYSTALLINE SILICON	* NO CANADIAN MANUFACTURER * IMPORTED CELLS AND MODULES (EXCEPT SMALL BESTEK MODULES)
AMORPHOUS SILICON	* UNIVERSITY RESEARCH * ALL MODULES IMPORTED
CdTe	* UNIVERSITIES, SILONEX, TPK * RESEARCH STAGE ONLY
CuInSe ₂	* UNIVERSITIES SUCH AS MCGILL * SOME INDUSTRIAL RESEARCH ORGANIZATIONS * RESEARCH STAGE ONLY
GaAs	* SOME UNIVERSITY RESEARCH

SLIDE NUMBER 20

WHAT PV WILL AND WILL NOT DO - MR. DONALD E. SIMMONDS

(Mr. Simmonds is General Manager of Lenbrook Industries Ltd., of Pickering , Ontario , a major Canadian marketer of PV systems and hardware)

My objective this morning is to give you an overall impression of the capabilities and limitations of photovoltaic applications. My comments are distilled from our experience supplying almost four thousand photovoltaic systems, the majority of which are within Canada.

The largest number of these systems are powering navigational aids or telecommunications equipment; the remainder, a variety of applications ranging from sailboats to weather stations.

I want to set a ground rule down first, and that is that I'm a businessman, not an engineer, recognizing that I'm facing many technical people in the audience today.

To address the topic of what photovoltaics will and will not do, let me draw a business analogy. As I observe successful businesses, they are managed by people who know what business they are in. They know their strengths, their interests, their own personalities, the resources available to them. They attempt activities which are in line with these strengths.

I also notice that successful businesses are managed by people who know what businesses they are not in. They make decisions to avoid activities which will hurt them. They don't take on projects which they cannot handle well.

It's no great mystery, then, that photovoltaic power systems are no different. We are talking about an exciting and very feasible, present-day power technology. Successful installations will be designed and installed by people who know and clearly understand the liberating advantages of photovoltaic systems: what they will do. Successful installations will be designed and installed by people who know and clearly understand the limitations of photovoltaic systems: what they will not do.

Thank you, for putting this topic on our agenda today. It's my hope that in the next few minutes I can outline

some parameters of PV systems which will give us lots of confidence to make use of photovoltaic technology in the applications which are most suitable for it.

Now, like all good marketers, I'm going to start with a negative. In fact, I'm going to address three limits of PV technology and three capabilities. Anything more than three, and I get confused, so I'll start with the negative and then I'll go to the positive and so forth.

The first, as Dr. Thomas mentioned, which becomes a focal point, perhaps, of the limitations of this technology, is cost. It is a limiting factor to widespread use. When you consider a system that would cost eighteen to twenty thousand Canadian dollars to operate a hundred-watt lightbulb twenty-four hours a day, it gives you an idea of the fact that it is a relatively expensive power source.

It is not generally a technology which will provide heat, for instance, at a remote telecommunications site at which you want to heat the building. It is not an energy source which, in the near term, at least, will displace conventional, utility-generated power as we know it here in North America.

In fact, for virtually every system which PV operates today, there has been an economic cross-over point and there has been an analysis of various power alternatives, which has resulted in pointing the way for PV power sources.

On the other hand, there are some very interesting cost-effective benefits in using photovoltaics. This is one of its great capabilities today. When a proper, total power economy analysis is carried out, photovoltaic systems can be very economical indeed. In fact, many of our customers are realizing a total capital-cost recovery on their systems of less than two years.

---SLIDE NO. 21

I won't take much time on this, but I want you to get the general overview of the capabilities, cost-wise, of alternative sources of power.

It's called, "Economic Demands for Selected Power Technology." You may have seen this before --Department

of Energy, United States. The vertical axis is really the cost of the power produced by the alternative. The horizontal axis is really an indication of the daily loads.

Simply, in blocks, you can see that in very, very small requirements, batteries are still an alternative. Perhaps next come electric generators, and then a wider range for diesel.

Crossing those alternatives are various applications for photovoltaics, stopping short, of course, at utility-generated sources of power.

---SLIDE NO. 22

While photovoltaic systems are gaining acceptance, its full cost-effectiveness is largely unknown to experienced applications engineers. In Canada, for instance, we give leadership in communications, but we can hardly say that we have even begun to utilize photovoltaic power systems to power such applications.

Let me refer, if I might, to a consultant. This is Bernard McNellis, a man who does eighty percent of his consulting business in the third world, obviously associated with many forms of power supplies.

"In the early days, makers and promoters of photovoltaics needed to talk about the future because PV was so expensive. Those days are over, and frankly, the future is irrelevant. First, no one can predict it; second, PV is economical now at its present cost.

"In fact, for applications like water-pumping and telecommunications systems in the developing world, the cost of not using PV may be prohibitive. Any other power source may prove too expensive or troublesome to be used at all.

"In Africa or southeast Asia, for instance, one alternative is doing without anything, but PV can actually make something like a telecommunications system possible. Putting a microwave repeater station on a remote, inaccessible mountaintop could easily be both logistically and economically out of the question without PV."

Relative to costs, the main competition is diesel generators. It's very obvious that, for remote power needs in the 100-kilowatt to 200-kilowatt range, diesel is the only way to go. That has been the case and probably will continue to be in the near future, but for literally hundreds of thousands of other, smaller applications, PV is absolutely the way to go.

The simple fact is, when you compare the true life-cycle cost of PV versus diesel -- that is capital and operating, including maintenance -- PV comes out ahead.

Another limitation of photovoltaic systems is geography. I'd say the most obvious one in this respect is the amount of available sunlight at a given location. However, that gets most of the attention. There are also some site-specific limitations relating to geography.

We bid a system one time in northern Ontario, where we actually bid a system that was over three times as large as the next largest bidder. The cost reflected as such. We came to find, however, as the only bidder who had gone in to look at that site, that the others had not realized that, until ten in the morning, the sun did not come up over the trees and it sunk behind the shade again at two in the afternoon, and as a Ministry of Natural Resources application, those trees could not be cut down. We have a geographical, site-specific problem there which has severe ramifications to the cost of providing power at that site.

The other interesting thing about photovoltaics that perhaps doesn't come to mind right away: Because they require outdoor exposure, they are also subject to such things as vandalism, and while many of them are installed remotely, it's amazing how many people come across them.

I have a sample of such, a beautiful solar panel which one of our customers sent to us, asking us for a free replacement, indicating that we could use this for publicity if we would just give them a replacement panel, which we did.

That brings me to my next capability of photovoltaics, which is the fact that it is a very sound technology. It may surprise you, but this panel operated well until the technician went back with the replacement panel three months after the damage was done, and was operating at

full rated capacity.

It's a sound technology, ladies and gentlemen. Out of many renewable sources and, indeed, the available power alternatives for small power applications, which I call 100-watt continuous load and under, we believe in the long-term benefits of photovoltaics. Solar cells are non-polluting. They operate with no moving parts. These are very significant characteristics.

In the seven years of involvement that we've had in this technology, it's proven itself to us many times. It is not a gimmick anymore. It's a mature technology, which, rightfully used, provides enhanced reliability and huge cost savings.

We have one installation that's a hundred and fifty miles from the north pole. The capital cost of this system was less than \$30,000. It's providing cost savings of \$240,000 per annum for that particular customer. Many users are now beginning to participate in similar significant cost savings.

Another limitation: I refer to it as "intolerant system design." Intolerant system design: perhaps, one of the key limitations to the people in this room today, to contemplate a few. The high cost of this power requires a close projection of load demands and a very tight system design to minimize costs. Only a slight deviation, however, in the load can be tolerated. This is unlike alternatives like diesel, which tend to have a lot of float or a lot of play in the system design.

For instance -- fortunately, this was not one of our customers at the time -- but there were seven major photovoltaic communications sites that went down on the coast of Newfoundland a couple of years ago. It happened because, just at the last moment before the radios were shipped, Motorola, who was the supplier in this case, made a slight design change to the circuitry in those radios, demanding a higher load. No one ever considered making a change to the design of the solar system. It worked for two years until, one January, there was an unfortunate amount of fog that year, and suddenly, the systems crashed. Batteries froze -- huge losses. I refer to that as the "intolerant system design," the nature of photovoltaic system design.

To avoid such disastrous results and to avoid giving photovoltaics a bad reputation, it is incumbent on users of photovoltaics to ensure that a reliable system design and load estimation along with a double-checking routine is contemplated so that the intolerant relationship between the load and the power system stays closely aligned.

We've just received a contract where we have actually redesigned thirty-seven solar systems six times since we began. That's an awful lot of work but the only way to end up with the right sort of result. This redesign simply took place after there was a re-evaluation of the communications site and a load change and so forth, and it's the only way to handle it, really.

That brings me to my final point. It is the fantastic capability of photovoltaics, and that is its high reliability. The reliability of photovoltaic systems, frankly, is truly remarkable.

By their very nature, they are installed in the harshest of environments. Mountaintops, icebergs, small clearings in the bush: They all represent the ultimate home for photovoltaic modules. We are pleasantly surprised to see how well solar cells, when properly encapsulated, stand up over years and years.

Our own failure experience is so minimal that it does not register on the computer printout. It is rare to find a product or technology with the positive operating record of photovoltaics.

I have listed three of the limitations of photovoltaic systems: cost, geography, intolerant system design; and just three of the capabilities: cost-effectiveness, the soundness of the technology itself, and its high reliability.

I hope this has encouraged you in a general sense to urgently consider the utilization of photovoltaic systems in suitable applications. Let me quote the president of Solarex.

"Times have changed and the future has arrived. The indisputable fact is that, in thousands of instances, photovoltaics is the clear choice of power alternatives. This remains true despite the falling price and easy

availability of oil."

Will PV prices fall in the future? Of course, they will, but that is irrelevant to the engineer who must choose among competing technologies today. It is incumbent on decision makers to wipe out the misconceptions of the past and to make realistic comparisons on a sound economic basis.

When such rigorous comparisons are made, photovoltaics is frequently the clear technology of choice, not sometime in the future, but today. Thank you very much.

CURRENT APPLICATIONS IN CANADA - MR. SUNNY LEUNG

(Mr. Leung is with the Marine Aids Division of the Canadian Coast Guard, Ottawa and is in charge of their PV conversion programs)

One of the major functions of the Canadian Coast Guard is to provide marine aids to navigation in Canadian waters within the federal jurisdiction.

---SLIDE NO. 23

As you can see from this map, we look after the three coasts of the ocean: the Atlantic, the Pacific, and the Arctic. In the middle, we have Hudson's Bay. Up north there, we have the two thousand miles of the Mackenzie waterways. We have the Great Lakes in the south and the six hundred miles of the St. Lawrence Seaway. When you get all those coastal lines together, there is between twenty to thirty thousand miles, and that's our responsibility.

---SLIDE NO. 24

Before we go further, I just wanted to show you some of the navigational aid configurations we use. Now, this is just one of those minor aids we've put out in Lake Erie and Ontario.

This is a lantern, and inside, there is a little light bulb there, and you press the electronic switches and the lamp changes and it flashes.

---SLIDE NO. 25

This one is along the St. Lawrence River. It's one of the aids that we use.

---SLIDE NO. 26

This one is on the Saguenay River in Quebec.

---SLIDE NO. 27

This is one of those small aids on the east coast, I believe in the P.E.I. area.

---SLIDE NO. 28

This one is in St. John's, Newfoundland.

---SLIDE NO. 29

This one is one of the arrangement up in the high arctic near Resolute Bay. We've had this one up since '79.

---SLIDE NO. 30

This is one of the major lighthouses in Lake Erie.

---SLIDE NO. 31

This is one of the navigational buoys. It happens that this one is a solar buoy on test in navigation, and the location is on the east coast between Nova Scotia and P.E.I.

---SLIDE NO. 32

This is one of the major stations on Sable Island. Recently, we converted to solar.

---SLIDE NO. 33

This is one of the major light stations just outside Kingston. We converted this from diesel power to solar power roughly five years ago.

---SLIDE NO. 34

This is an automatic timer that we incorporated with the smaller aids, where they only are seasonally operated, and the timer is programmed in such a way that the aids themselves can be shut off and turned on automatically.

That gives you some idea of what we're doing, but of course, these are only small aids we're talking about, and we have roughly eight thousand of those aids in Canada.

Moving upwards from the smaller aids, we have the light stations. In the light stations, we have high intensity beacons and the foghorns and the fog detectors and the radio monitoring equipment, which we can use up to a hundred watts. A little further from this would be the

major radio station, which we deployed a hundred kilowatts of power, but of course, in today's topic, we concentrate on the smaller aids, and we find the photovoltaic power is the most cost-effective.

As some of you can recall, when we first spoke of the subject of photovoltaics at the symposium in '79, at that time, we mentioned that we had been testing photovoltaic systems since 1972, and we had produced a specification for procurement, and we were just about to implement a conversion program for our minor aids from primary batteries to photovoltaic power.

At this point in 1986, we have purchased approximately seventeen hundred systems and delivered. At the moment, fifteen hundred of these are installed and operating.

---SLIDE NO. 35

This is the breakdown. For the land-based aids, we have around five thousand. The number of radio transformers, we have one hundred. The number of minor lighted buoys, we have three thousand. Major light stations, we have two hundred seventy. The number of telecom sites are roughly a hundred. The figures with the brackets are the figures we think can be converted to solar.

---SLIDE NO. 36

Prior to 1983, in all the solar panels we used, we used single-crystal technology. After 1983, we qualified one company which used Semrx, so at the moment, we have panels from both technologies. The other technologies that Dr. Thomas mentioned like the amorphous, we have not tested and we have not approved those technologies.

The PV program in the Coast Guard is very successful. Usually, many centralized programs which come out in Ottawa are not as hot as this one, but this one seems to be a very great success to us, and just about all the districts across the country would like to implement the program and would like to implement the program to the fullest extent.

The reason we switched to photovoltaics is just a matter of economics. The cost savings, of course, will make it, in time, worthwhile.

To the engineer and the technician in the field, increasing reliability means they don't have to stumble uphill and downhill with their arms full of disposable primary batteries. I certainly would like to be able to quantify the increased reliability factor for myself and every one of you here in this room. However, the Coast Guard report system does not include the minor aids to navigation, so I guess you have to take my word for it.

I can give you assurance that every one of us from our division are happy with the photovoltaic systems, and they rated the reliability of photovoltaics just as good as the commercial power which comes to your home, and certainly, they are much more reliable than the disposable batteries and the diesel generator.

Now, of course, we're not really expecting it to be perpetual. There is no such thing, and we do have some failures.

---SLIDE NO. 37

Now, the failures contributed to the system, we can summarize into roughly five categories. The first one is vandalism. I don't have any picture to show to you, but you can imagine that, if there's a tower without a top, that's vandalism. They stole it. The next one would be the corrosion.

---SLIDE NO. 38

Now, this is vandalism. They throw rocks at it and sometimes they use shotguns.

---SLIDE NO. 39

Talking about corrosion, you can see all the interconnect corroded away, so you have corrosive action of the sea water, which seeps right into the lamination of the module through the junction box.

Now, one picture explains more than ten thousand words, so this picture explains forcefully that our standards must remain high. A lot of times, we've been criticized by some suppliers, saying that our specifications are too stringent for them to supply, but we say, "Well, we don't agree," and this picture shows the reason we have to stick to our guns for a tougher specification.

In addition to that, we figure we must also enforce using tighter quality-control measures to qualify the product even though they've been tested and accepted by the Coast Guard.

Now, what's interesting to note: While we talk about a lot of failures with the corrosion aspect and the vandalism, the other form of failure is due to environmental conditions. There may be too many foggy days and too many rainy days, and also, the annual sun insolation is very low, but those failures constitute a very small percentage of the total failure.

The solar batteries and the regulator seem to work very well. We have very little failure reported on this area at all.

The vandalism, we can prevent by introducing vandal-proof type of hardware and also, in some locations, we can use a laminate on top of the glass so that they won't be able to damage the module by means of throwing rocks.

The corrosion aspect, I already said before, we have to test the module to make sure the supplier meets the installation requirements.

In regard to the low-insolation aspect, what we can do is to make the design more generous, make the battery capacity much bigger than we need, and also, if possible, we can make the module quantify more than is required.

As far as the location where PV cannot be used because of the foggy days or they're too long and the insolation is too low, those areas, we've found, are only very minimal. There's not too many of them around in Canada.

Now, despite all the severe weather we have, the extreme temperatures across Canada, so far the photovoltaic performance in the Coast Guard has been very satisfactory, and we must credit our success to our design.

We've said a lot about failure in the past few moments, and certainly, we'd like to put things back into perspective and remind you that, actually the failure rates of photovoltaic systems have been extremely low.

The Coast Guard will proceed, therefore, with its conversion in minor aids to navigation until the use of primary batteries is virtually eliminated. So far, substantial progress has been made. In the first year when we started the conversion, fiscal year '80-'81, we bought over 21,000 primary batteries. In 1986, the figure has fallen to fifteen hundred.

Now, for those of you who are conservationists, or who worry about ecology, I've got good news for you. The Coast Guard this year will have to dispose of 19,500 fewer batteries in a, quote, "environmentally accepted fashion."

The next thing we talked about is the buoy conversion. That presents a very special problem because the buoys move, whereas the land-based stay on land and they don't move, so the battery we use is supposed to be spill-proof, but those batteries are actually not leak-proof. When the buoy tilts, the electrolytes still spill, so we've been looking for something which is absolutely leak-proof.

Fortunately, after 2 1/2 years, I think we have found our answer. We believe we've found a battery which meets our criteria with a reasonable, long life. They are reasonably priced as well, so the wholesale conversion of buoys to solar buoys is technically feasible and economical. Our conversion is scheduled to start in the fiscal year '87 to '88.

Finally, I would like to mention a few things about the last system we were talking about. First, we mentioned the land-based aids; then, we mentioned the buoys; and now, we'd like to mention a little bit more about the light stations.

At the moment, we have two hundred and seventy of them, and we figure between thirty to eighty of those light stations can be converted to solar because we have just started our augmenting program.

This means the keeper in the light station will be removed. After they've been removed, that means that the domestic loads are going to be eliminated. With that eliminated, what's left behind will be the station load, which is economical for us to make solar.

At the moment, we have ten of the light stations converted to solar, and they've been functioning quite well, but for the much larger load, we find that we might be thinking of hybrid systems with solar and diesel. Of course, our design criteria is such that the solar can carry as much of the load as possible and the diesel generator would be used as the stand-by supply and also the emergency supply.

This is the present status of the Coast Guard program to date on solar generating electricity. Thank you.



SLIDE NUMBER 23

Conversion Program (Fiscal Year 80/81)

Small Systems (under 200 Wp)	1700 procured & delivered	1500 installed
Large Systems (under 2.5 KWp)	10 procured & delivered	7 installed

SLIDE NUMBER 24

Numbers of Minor Lighted & Land Based Aids	5000 (2600)
Numbers of Radar Transponders	100 (100)
Numbers of Minor Lighted Floating Aids	3000 (2000)
Numbers of Major Lightstations	270 (30-80)
Numbers of Telecom Sites	100 (50)

SLIDE NUMBER 25

System Types

Before 1983 - Single Crystal Modules

After 1983 - Single Crystal and Polycrystal Modules

- Modules using other technologies -
have not been approved

SLIDE NUMBER 36

Failures (5 Categories)

- Vandalism
- Corrosion
- Environmental Factors
- Regulators
- Storage Batteries

SLIDE NUMBER 37

REVIEW OF SYSTEM COMPONENTS - MR. E.E. KALMBACH

(Mr. Kalmbach is Manager, Energy Division, of Lenbrook Industries Ltd., of Pickering ,Ontario, a major Canadian marketer of PV modules and systems.)

I can't think of another topic that I am more interested in between the hours of eight till five, and usually going on into the evening.

Photovoltaics, from my particular point of view, is the ideal choice for virtually all remote telecommunications sites in Canada. The emphasis this week here at the show has been on telecom applications, and it's only fitting that we highlight this particular technology.

This morning, what I'd like to do is give a basic overview of system components in a photovoltaic system. Then we'll take a look at sizing a system, which is very important.

I was particularly interested this morning in the Coast Guard presentation where they indicated how they decided if vandalism had occurred. If they looked at the top and nothing was there, somebody took it. Now, that could be related to system design as well as ingenious vandals.

This morning, I think, if we take a look at proper system design, including structures, vandal-proof hardware, and the like, there are some ways of circumventing this from happening.

---SLIDE NO. 40

For a system overview, there are three general headings: system types and configuration, system components, and system design. Mr. Bill Rever of Solarex Corporation will be assisting on the system design aspect.

---SLIDE NO. 41

I think you can briefly divide photovoltaic systems into three categories, beginning with the stand-alone photovoltaic system. The stand-alone system is probably the one used in ninety-five percent of the applications that we're involved with, and this can be further sub-divided into two categories: those systems with storage battery

and those without storage battery.

The stand-alone systems that incorporate a secondary battery are those which have to operate twenty-four hours a day or some portion thereof, including those hours when the sun is not shining.

Battery storage batteries will be discussed later at a specific seminar. Typically, in Canada we look at a range of ten to twenty -- in some cases, twenty-five -- days autonomy for critical applications.

Now, I understand the Coast Guard has systems with much higher autonomy, and it's usually based on the experience of the individual users, what degree and the degree of "criticalness," if I can say the word, of the application.

Those applications without battery storage: The initial one that comes to mind is water-pumping. That's where you can utilize some other type of storage if required, such as hydraulic storage.

In some African countries, we have systems which begin pumping as soon as the sun comes up. They pump as much water as they can all day, which is stored at, perhaps, an elevated holding tank, and then they stop pumping when the sun goes down.

You eliminate the inefficiencies associated with voltage controllers and batteries in this type of system. However, it is not much use should you require power in the middle of the night. Typically, for telecom applications, you require twenty-four hour a day power. Therefore, you would go with the storage battery stand-alone system.

Now, unique to Canada, perhaps, is the ruggedness and the high altitude. The U.S., other than Alaska, does not have that type of problem. As you go higher, as you realize, in latitude, the higher you go, the less sunlight you have in the winter. However, in the summertime, you have considerably more sunlight than you do at lower latitudes.

We have one system right now. It's approximately eighty-two degrees north latitude, and it was producing measurable power at 1:30 a.m. in the morning. That was

with a south-facing array, simply due to the fact that, during the months of June and July, the sun never really sets and it was operating off reflected sunlight. However, for year-round applications, a hybrid system is probably the way to go for extreme northern latitudes.

The wind turbine is in the same category as photovoltaics. It requires no fuel source other than wind; photovoltaics require no fuel source other than the sun, so it would probably be suitable for, at this point in its development, smaller applications. For larger applications, some type of engine, perhaps diesel, would be incorporated.

That can further be sub-divided, as you notice, into battery-charging and direct load. If it was a battery-charging system, you would have a typical system, the same as the stand-alone indicated at the top, where you have the solar array charge controllers feeding into a battery-storage system. Then you would have a diesel, which would be connected in parallel to the battery system.

You have some type of transfer switch triggered by the state of charge of the batteries. At a certain state of charge, it would automatically switch over, turn on the diesel or the other form of generator, which would supplement the charging of the batteries.

It can also operate direct load. In this configuration, there is no or very little storage. It is connected directly to the load. During the daylight hours, perhaps the equipment would operate off the solar array and, when that was insufficient, directly off the other type of generator.

The third broad category is utility-interactive systems, further divided into two subsections. Some are used for back-up systems. There are certain countries of the world where the utility-supplied electricity is not reliable. It can cease at any point in the day. In these countries, the back-up system would be, probably, a necessity for critical equipment.

Sell-back arrangement: I'm not sure of the present state in Canada. Some countries are further developed than others in this arrangement whereby you generate electricity from the photovoltaics array. It is fed into

the utility line and two-way meters are installed. Credit is given for excess energy produced. It's not a common application in Canada.

---SLIDE NO. 42

System components: Now, we heard this morning about the fabrication and the various technologies of solar cells. I'm going to take it from that point. The solar cell is produced and then it is fabricated into a solar module.

The solar module comprises a number of cells which are interconnected. Typically, each cell produces approximately half a volt, so therefore, they must be connected in series to provide adequate voltage for charging battery systems.

Modules have varying numbers of cells, ranging from, perhaps, thirty-two to forty, depending on the particular application. A thirty-two cell module would be used primarily where you would be coupling it directly to a DC motor. On the other end, forty-cell modules are typically used in extremely hot climates where the voltage decreases with increasing temperature, so to maintain adequate charging voltage in some applications, forty-cell modules are utilized.

Just a brief note on construction: There's a number of different types of module construction. This particular one has a tempered-glass face with high transmissivity. It has a layer of ethylene vinyl acetate. It has the cell assembly, followed by another layer of e.v.a., followed by a backing of Tedlar.

That's the laminated type of module. There are cast type of modules, there are glass-on-glass modules, and perhaps a couple of other types of construction.

The module itself or the "lamwich," as some people refer to it, is mounted, generally, in an aluminum frame. The frame must be anodized -- there are different types of processes -- to prevent corrosion.

The back of the module, you'll notice, has some type of output junction box. That particular one over there has the back removed. The output from the cells comes into the junction box, and in the case of this Solarex module here, there are four wires coming out. The module can be

run in either a six-volt nominal mode or in a twelve-volt mode by series or parallelling the output connectors. Taking an individual module, they are then assembled into panels.

---SLIDE NO. 43

A simple DC system is the PV modules connected to some type of DC interface and regulation circuitry to a battery bank. The load is taken off, generally, the controller, a very simple system, the basic components.

You have the sunlight coming in, striking the face of the array. You have the output from the voltage regulator of some type with, perhaps, a blocking diode or some means of preventing the battery from discharging back into the array, the battery storage, and finally, the load.

There are different forms -- and we won't go into this; it was discussed this morning -- of producing the cells. A cell is, as we just mentioned, incorporated into a laminated assembly, which is then mounted into a module.

For definition purposes, we start with the solar cell. Some are round; some are square. They are formed into a module. A module is assembled into a panel. A panel is then assembled into an array.

These may vary in size. There are hundreds of systems this size across Canada, powering monitoring equipment, data collection platforms, all types of small power requirements.

This module with a regulator and a battery is every bit a system as a thousand modules and controllers and batteries. It's simply the complete number of components to produce a power system.

In system design, generally, you start at the module level and incorporate the modules, panels, and arrays into suitable configurations to meet both the load and the mechanical requirements.

---SLIDE NO. 44

A very simple diagram. In order to supply forty-eight volts, you simply series-connect four, twelve-volt modules. That's generally the nominal voltage. When

you're looking at battery-charging, it's so many volts per cell. The module has to be designed in order to adequately charge.

---SLIDE NO. 45

Building up to the array, the various components, we have the photovoltaic module. Then we need a mounting structure, which is generally fabricated from anodized aluminum or some other lightweight, high-strength material. We have the nuts, bolts, washers, which are generally, in most arrays, out of stainless steel.

We have cabling. We have intermodule cabling, those cables which connect one module to the next. That has to be out of a highly environmentally resistant material, the coating, typically an F.D.O. type cable, which has properties of remaining flexible at extreme temperature excursions. It has to be impervious to ultra-violet radiation. It cannot deteriorate within the design lifetime of the system.

On the back of the module, you have the module junction box. Generally, on a large system, the output from various panels is terminated in another type of junction box. This can be a NEMA 4 type enclosure, water-tight, generally corrosion-resistant.

The modules themselves have been subjected to accelerated life testing. I think a forty-year life is expected on a number of modules. Therefore, the balance of the system components should really comply with the design life of the modules themselves.

Regulators come next. They will be discussed in greater detail later on. For example, this is a regulator that is supplied to telecom applications. It's highly reliable. It's in a NEMA 4 type enclosure with water-tight entry glands.

For the small systems I mentioned earlier, a new product: a relatively small regulator which will handle up to six amps. This can be mounted right in the junction box and connected directly to the output of the module. Then the output from that particular module is regulated and no further equipment is required.

The design of solar structures, mounting structures, is

important. The environment, as mentioned earlier, is very harsh, and if you came out to your site and all you noticed was the structure and no array, then you would know, as the Coast Guard knows, that something is wrong.

The structures typically are constructed from galvanized steel, hot-dip galvanized, aluminum, and stainless steel. Our experience has been that, on a number of salt-water applications, those mounted near the ocean, stainless steel seems to be an ideal material. It's high-strength. It's corrosion resistant, and because of its strength, smaller sized members can be used than the basic galvanized steel construction.

---SLIDE NO. 46

This basically shows the output of a panel coming down, and again, some customers require metal back-plates on their modules. This has a couple of functions. One is to reduce damage from vandalism, throwing rocks. I think it will probably deflect a small-gauge, perhaps a twenty-two calibre, rifle shot from some distance. Also, in the wintertime, on coastal regions, there is a lot of blowing ice, chunks of ice, and things like this. That protects the rear of the module.

The junction boxes, as mentioned, have water-tight glands because you do not want moisture penetrating the box and causing corrosion at the metal connections.

---SLIDE NO. 47

That's an awkward angle. That's a stainless steel metal trough for cabling to keep it out of the way of rodents, which are a problem in some cases. There's a grid on the back of this structure for installation and future monitoring, opening junction boxes and taking readings.

---SLIDE NO. 48

The structures: There is one that is mounted twelve feet high, the reason being that ice forms on the edge of the lakes, and as winter progresses, the ice is pushed farther up the shore, and in order to eliminate damage from the array, the modules must be mounted at an elevated location.

Farther inland, it is not such a severe concern.

However, snow is also a concern in Canada in northern latitudes, and the array must be mounted above the snow line.

Very briefly, those are system components. In Canada we have some unique problems and challenges in designing systems. As I mentioned, ice, snow, and temperatures all play a part in system design. At this point, I'm going to ask Bill Rever of Solarex Corporation to continue with the system design.

SYSTEM DESIGN BASICS - MR. WILLIAM B. REVER

(Mr. Rever is Product Manager, Systems, for the Solarex Corp. of Rockville , Maryland, USA, one of the world's largest producers of PV modules and hardware.)

I'd like to try to briefly cover in a quick fashion the subject of PV system design. It's really a little bit too complicated to cover in great detail in twenty minutes, but what I'd really like to leave you with is the information that you need to know to design a PV system and a rough method of calculating PV system sizes.

---SLIDE NO. 49

First, I'm going to go through the parameters and information you need to determine your system size, and then I'm going to go through the design process and a couple of different ways of carrying that out and breaking that down into electrical, mechanical, and the system sizing and dimensioning aspects.

There are a number of different categories of load parameters that you need to know in order to properly design a PV system. The most important parameter, as was brought up earlier by Don Simmonds in his presentation, is that you really have to know your load requirements.

Especially, you have to know the voltage requirement of the devices that you're powering, and very important is what voltage tolerance they'll accept. The reason is that, in the normal operation of a PV system, the batteries will be cycled from a fairly low state of charge up through a fairly high state of charge. This can vary the operating voltage of the system by a factor of about twenty-five percent.

On a typical twelve-volt nominal system, that would go anywhere from about twelve volts up to as much as fifteen volts, so you need to know your load voltage and its tolerance.

Additionally, and this is where a lot of homework sometimes comes in, is finding out what is the amperage-hour draw of the load on a daily basis. If there is a

variation in that, you need to know what the variation of that load is with regard to the month of the year because the most basic PV design process is matching the energy received by the array and transmitted through the battery and control system to match that energy to the energy draw of the load on a daily basis.

That leads us to our next most important parameter, and that is the insolation. What that is, is the total amount of solar radiation received on a surface at a given site. This information is compiled by a lot of different sources. We'll get to that in a minute, but it's very important that that information be accurate. If that's not accurate, your whole system design is going to be thrown off.

The third most important factor is the temperatures to be expected at the site. Basically, you need to know two different types of temperature information. You need to know the design extremes. You need to know what minimum and absolute maximum you're going to have to tolerate as far as your materials are concerned.

That's mostly important from the standpoint of, actually, both mechanical and electrical in terms of what types of temperature extremes the materials that are used are going to be able to withstand. Additionally, electrically, since a PV cell has a voltage loss at increased temperature, you need to know whether there is going to be sufficient voltage to charge the battery system during the hot point of the temperature cycle.

Also, of course, on the minimum temperature side, you have to worry about the battery storage capacity because the lead-acid battery, which is typically the battery used in photovoltaic systems, loses capacity very sharply at decreased temperature levels, and it can result in having to oversize batteries by as much as one hundred percent over values that you would use at normal temperature conditions.

The fourth factor that you need to put into your system design process is the overall system reliability. This is also an important number because a PV system design is really a process in probability analysis because the sun, of course, on any given day, is a random variable. You never know exactly how much you're going to get on a given day, so the design of a particular PV system is

really designed around achieving a certain degree of reliability. As you go higher and higher in the system reliability, of course, you'll need larger and larger PV array and battery components, so these are important parameters to specify.

You also, of course, need to know your environmental conditions. What is the expected range of humidities? Is there a salt-spray environment which might necessitate use of especially corrosion-resistant materials? Is there a particularly dusty environment which may also focus a need on having to have particular types of enclosures or even increased maintenance on the system due to having to wash the dust off the array or that type of thing?

A very important factor in the mechanical design of the system is what is the expected wind load. At Solarex, we typically design all of our structures to withstand 125 miles per hour, which satisfies the most stringent wind codes in the United States, but this can be dictated either higher or lower depending on the site conditions. We've had cases where we've had to design for up to 160 miles per hour, and we've also had cases where we only wanted to design to 80 miles per hour.

Finally, you get into site-condition aspects such as soil conditions. This is important from the standpoint of putting in array foundations and choosing the most cost-effective type of structure for use in a given application. We make several different types of standard structures to try to accommodate different soil conditions and different site conditions, from very simple types of structures using pipes and poles that are very useful in areas where there's no heavy equipment or where you're going to have to rely a lot on hand labour all the way up to highly automated kinds of foundations that would be installed by heavy equipment.

You also have to take into account a factor that sometimes is not known and sometimes is hard to determine unless you visit the site or have people who have been there, and that is what is the shadowing condition. As Don mentioned in his presentation, you can run into situations where the textbook data will indicate that you have a certain amount of sun, but when you get there, you find that either trees or mountains or buildings, even, in some cases, limit the amount of sunlight available, so

that's also a very important thing to take into consideration.

Finally, you may have array-orientation considerations. We have run into this in several of our projects where we didn't have control over the site layout. We've found that, in some cases, we had to install our systems, say, in the northern hemisphere, on the northern side of a tall transmitter tower. Therefore, we had a shadow going across the surface of our array during the course of the day, which has caused not only a loss of power but can actually cause failures, depending on how the array is constructed and protected with diodes, so that's the other consideration you need to take into account.

Also, in some cases, you may be mounting PV onto a building and your orientation, therefore, will be fairly fixed. That will, of course, affect the amount of energy that you get out of the solar array because you won't be able to have the optimal configuration or it may cost too much to achieve the optimal orientation to the sun.

---SLIDE NO. 50

As I mentioned earlier, insolation is a very important parameter in terms of your system design. There are a couple of terms that are used in the industry that you need to be familiar with in the system design process.

The first is "total global radiation." What that means is basically the radiation that's received from the entire hemisphere of the sky. Typically, that unit is measured in langleys. Sometimes, it can also be measured in joules per square metre, and in the industry, we typically use a unit of kilowatt-hours per square metre, which, because the solar constant is one kilowatt per square metre, we also call an "equivalent peak sun hours". That's the unit that you'll hear most frequently in the PV industry.

Another term that's used quite frequently is the term "air mass." What "air mass" refers to is the effective path length of the light transmitted through the atmosphere. Usually, for the purposes of rating modules and general system design, we use an air mass of 1.5, which basically is a little bit more than you would have if you had the direct sun in an overhead condition.

You also have to take into account the clearness factors because the radiation that's received can be both direct and diffuse. In some climates, most of the radiation received will actually be in the form of diffuse light, especially true where you have a lot of overcast conditions.

On the other hand, in very dry and sunny areas, almost all the radiation received will be direct light. This will affect the system design because the direct component is a lot more predictable than the diffuse.

Finally, there are several different sources of information. The University of Wisconsin, quite a long time ago, compiled a set of data which is a good, ready reference for sites around the world. Additionally, the United States Solar Energy Research Institute has compiled a tabulation of data for points in the U.S. and U.S. territories.

Finally, if you're dealing with overseas applications, one of your best sources is often local authorities, the physics department of a local university or even the agriculture department, because, as you might guess, the sunlight availability is a very important factor in what types of agriculture you can carry out in a given area.

These things can be measured in a variety of different ways. The most accurate way is using a pyranometer. As far as practical field measurements are concerned, we typically use reference cells, which are simply calibrated solar cells. This is what you can use if you're out in the field trouble-shooting a system.

There are a variety of ways that you can calculate the insolation on a tilted surface. Generally speaking, you go through a calculation that's based on the geometry of the sun angle to the array plane and then you correct that for the diffuse insolation factor. I don't really have time to go into that calculation in detail. I do have it available and, if you're interested, I can send that out to you.

Finally, one of the most important things that has to be taken into consideration in the insolation is what is the daily variation. This is important because it affects how big a battery backup you need in order to guarantee the desired level of system reliability.

---SLIDE NO. 51

This is the set of calculations I was describing. As I said, I don't really have time today to go into this in great detail, but basically, what you do is you start out by predicting when the sun is going to rise on the plane of the array.

You basically go through and compute a cosine factor for the insolation on the surface of that array for the direct component. You then add in the diffuse component. Then there are probability distributions that you use to determine what the daily variation is that has to be taken into account.

What you end up with at the end result of this calculation is an approximation of what you're going to receive on a tilted surface. The whole point of this calculation really is to determine from the basic information which is measured on a horizontal plane -- to convert that into what you're actually going to receive on the plane of your array.

---SLIDE NO. 52

This graph shows a representation of the value of solar radiation over the course of a day under various kinds of atmospheric conditions. The highest curve on the chart is for a clear day. You can see that on a clear day, typically, the solar intensity ramps up fairly sharply, reaches a peak, and then ramps down fairly sharply in the afternoon.

Now, on a partly cloudy day, you can have very extreme variations in radiation intensity over the course of the day as the cloud cover goes in front of the sun. On an overcast day, you have a much diminished level of solar energy received, but in general, the PV array will still generate power, albeit at a diminished level.

---SLIDE NO. 53

This chart shows an example of how to do a shading calculation. What you need to do a shading calculation is a set of sun-angle charts. These are also available, and what you basically need to do is to determine when

objects that may be in the path of the sun are going to shadow the array.

Typically, you can see that the sun-angle chart basically just gives you a representation of the altitude and azimuth of the sun for given days of the year throughout the course of the day. Usually, for most design purposes, you're all right if you design so that you have sun from about eight in the morning to four in the afternoon because that's when the bulk of the energy for a given day is received.

---SLIDE NO. 54

I'd like to get in now to the electrical design process for the PV system. As we've discussed earlier, the first thing you have to do is determine the load voltage. Now, that will directly lead into determination of the number of solar cells or, in general, solar modules required in series, because the modules are generally the commercially available building blocks required to meet the load voltage.

This should be determined by the I.V. curves that are given out by the manufacturers on their data sheets. It's important at that point in the design process to make sure you're using the curve corrected for the expected operating temperature of the system.

From those I.V. curves, what you want to do is determine how many in series you need to achieve full battery charging. You need to find out what level of battery voltage is required to achieve full charge. It varies somewhat, depending on the composition of the alloys used in the batteries. Usually, you need at least 2.5 volts per cell to achieve a full battery charge.

It's important in this phase of your system design that you are on the short-circuit current side of the array peak power point. The reason for this is that there obviously is room for error in determining what your voltage drops are. There can be corrosion present on terminals and things like that, that result in other voltage drops that you want to account for, and if you design your system to be to the open-circuit side of the peak power point, any small increase in the voltage drops will result in a large decrease in the amount of current available from the array. so you need to make sure that,

at your highest temperature operating point, you're not on the open-circuit side of the peak power point of the array.

---SLIDE NO. 55

The next phase of the analysis is really looking at the current side. This is your system-sizing or array-dimensioning calculation. First, you have to determine the worst-case current-drawn ampere-hours per day. As I mentioned earlier, your load information is very important. If you don't have the correct load, you're not going to have the correct array size.

You have to account at that stage for coulombic losses in the battery system. Typically, we use a value of ten percent as representative of the amount of ampere-hour losses that occur in lead-acid batteries under normal operating conditions. It's kind of a rule of thumb, but it's fairly accurate for batteries that are between eighty and one hundred percent state of charge. In a well designed PV system, your battery is going to spend most of its life hovering between those two areas.

Again, this is a rough sizing-type calculation, but in a hand sizing analysis, you have to put in some factor to account for things like dust build-up on the surface of the array, variations in insolation from its monthly value et cetera. Usually, we use a value of ten percent here.

The result of these two calculations is a total load requirement that has to be supplied by the PV array on a daily basis.

Now, from the site location and latitude, you have to next determine what is going to be the design insolation value in the worst-case month. That can be done by a variety of methods, either using charts -- there are charts of the world available -- or tables of insolation values or, if you are really going a sophisticated route, using a computer program. We use, of course, several computer programs, depending on the accuracy required and the complexity. What that will give you is how much sunlight you're really going to receive on the array plane.

Finally, what you have to do then is divide the total

load requirement by the amount of insolation. Fortunately, the units work out nicely as the equivalent sun-hour is the same unit as a kilowatt-hour per square metre. The result is the amount of amperes required from the array.

Your next step is to translate that into what your actual array size is in terms of commercially available product. What you need to do here is take the current that you determined was going to be output under the voltage conditions from the module I.V. curve that you found earlier. In other words, if you found out that your system was going to be operating at 16.5 volts, for example, at the module terminals, you read that off the appropriate I.V. curve and maybe get a number like 2.6 amps as coming out of your PV module at that voltage under the operating temperature conditions.

Now what you have to do is divide the amperage that you found out in the earlier calculation by that figure and that will tell you the number of PV modules of that particular type in parallel that is required to supply the array power needs.

From the previous calculations on voltage drops, you also found out how many modules in series you'd need, and now all you need to do is multiply that number by the number of modules in parallel to tell you the total number of modules for your whole array.

Of course, we haven't talked at all about battery size. That's a strong function of the climate. In the U.S., typically, five to seven days of storage is a rule-of-thumb type number. As you go, of course, higher and higher in northern latitudes, you need to have more and more battery storage because of not only poor sunlight conditions but there's a strong correlation with the variation in insolation to the level, so that the lower the level, the higher the variation. Therefore, in Canada, the rule of thumb is more on the order of fifteen days.

---SLIDE NO. 56

One of the computer programs we use, we call "Sunray II." I'm not going to go into this in a great deal of depth, but basically, it uses the same types of inputs that you would use for a hand calculation.

The computer program can be used to give you a number of different kinds of outputs. Of course, it can give you the insolation on tilted surface. A very useful tool that it can give you is what we call an "array battery trade-off graph." Basically, an array battery trade-off graph is simply a graphic representation of the fact that there are a series of points, combinations of array and battery size, which will satisfy a given reliability requirement.

At the extreme end, of course, you could have an array that only supplied the average amount of energy on a yearly basis and have an enormous battery. On the other side of the equation, you could have a very small battery if you had a very, very large array. Of course, the limit on that is about one or two days because you always need to be able to carry your load through the night.

Somewhere in between those two extremes, there's an optimal point, and in terms of economics and cost-effectiveness, like most optimization problems, it's not highly sensitive to how close you are to the exact optimum so that, usually, if you're looking at a range of system battery and system configurations, a number of different configurations would give you approximately the same cost and the same degree of reliability around the optimal point.

The key point about this computer program that we use is that it does an actual simulation over a number of years' period. This gives us a lot more confidence in the ability of the given PV system to meet the load, and we can actually print out a simulation of what the battery states of charge will be and the probabilities of different levels of battery states of charge, analyzed over up to a thirty-eight year period. That enables us to do a more accurate simulation and design of the overall system.

---SLIDE NO. 57

We've been discussing a lot about the electrical characteristics of the array and we have yet to see an array I.V. curve. That's what I want to get into now, the interaction between the battery and the array, and just show you graphically some of the things we've been

talking about in terms of voltage and current matching, and basically, also why the charging has to be controlled.

This chart shows you the charging characteristics, as an example, for lead-acid batteries at various states of charge. As you can see, under most conditions, the operating line, the load line, for a typical battery is almost vertical. What that means is that the operating voltage is virtually fixed by the battery. This is the most common operating mode of the stand-alone PV system. The battery voltage is fairly fixed and it drives the operating point of the entire system.

---SLIDE NO. 58

This is an illustration of that effect for batteries at a couple of different states of charge and for PV arrays under a couple of different light levels. The higher one is at one hundred percent of full sun and the other is at fifty percent of full sun.

You can see the phenomenon I was referring to earlier of wanting to be on the short-circuit current side of the peak power point. If you had designed the system so that you were too far over on that curve, you'd find that, under your higher states of charge, you wouldn't be able to deliver the full amount of array current into the battery.

---SLIDE NO. 59

This chart shows the same phenomenon on a little bit larger scale under typical operating conditions that you might expect to find in a solar array. Early in the morning and late in the evening, you have a low level of insolation represented by the lowermost I.V. curve on the chart. However, you're still able to charge into the battery, even at that low light level, if you've done your sizing properly and you have enough voltage.

As you go up in the day, the current level increases strongly but the battery voltage hardly changes at all, and so on, throughout the course of the day.

Until you reach the highest level of insolation around noon, you're still basically driving into the battery at the same voltage level. Of course, there will be some

small increase in battery voltage as it begins to charge up and go from, say, an eighty percent state of charge to a ninety percent or hundred percent state of charge.

Unfortunately, what this means is that you're seldom going to be operating an array directly at its peak power point. What it means is that, in reality, you're going to be actually getting fewer watts out of the PV array than its rated peak power, but that's one of the inherent characteristics of stand-alone P.V. system design. The only way of getting around that impedance-matching problem would be to use some kind of DC-DC conversion, which would not compensate, in general, for the efficiency losses encountered in the conversion process.

Well, that finishes up what I was about to say on P.V. system design. Thank you. If you'd like to receive a copy of that, unfortunately, I don't have copies of this part of the presentation, but if you could leave your card or, perhaps, mark one of the flyers that Lenbrook has, I'd be happy to send you a copy.

INFORMATION SOURCES - REPORTS - MR. DONALD J. ADKINSON

(Mr. Adkinson is president of Adkinson and Associates of Pickering Ontario, industrial consultants specializing in Photovoltaic technology)

Information is part of the stock in trade of the consultant. I'm going to talk to you today about one aspect of that. That is essentially where to look for information on various types of items relating to photovoltaics.

There are several aspects to this information question. One is that you've got to know what you're looking for if you want to know where to find it. Once you've found it, you've got to access it, and thirdly, you've got to do something with it.

I'm not going to try to cover all these aspects. I just want to tell you a few of the things and a few of the places where you can look for information on photovoltaics. One of the things that impressed me when I first entered this industry was the vast amount of information that is in print that is available on all aspects of photovoltaic technology design and economics. I am going to briefly go through these today and just cover them in slight detail and tell you just briefly what they are and who they are.

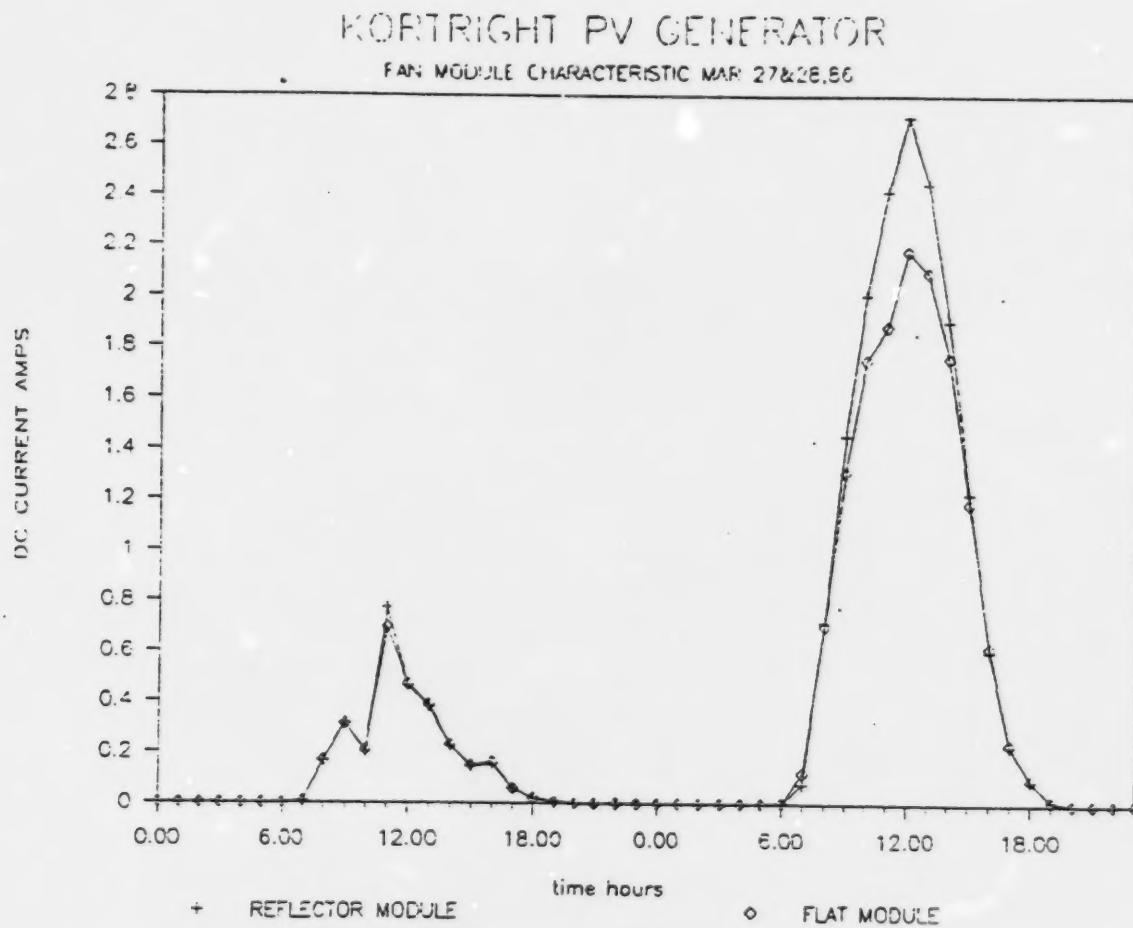
---SLIDE NO. 60

I'm looking first at institutions. Where are the centres of technical work going on in photovoltaics? These lists are not all-inclusive. Forgive me if I left some out, but I've tried to get some of the main ones that would be of interest to you or somebody who is looking for some information on a problem in an area of photovoltaic technology, be it economics or be it technical.

We have A.F.M.E., which is the French equivalent, so to speak, to the D.O.E., who look after the solar energy development work. They handle a lot of the projects undertaken and financed by their government.

The Brace Institute of Montreal is a low-tech organization working primarily in third-world countries and developing appropriate technology for rural, very

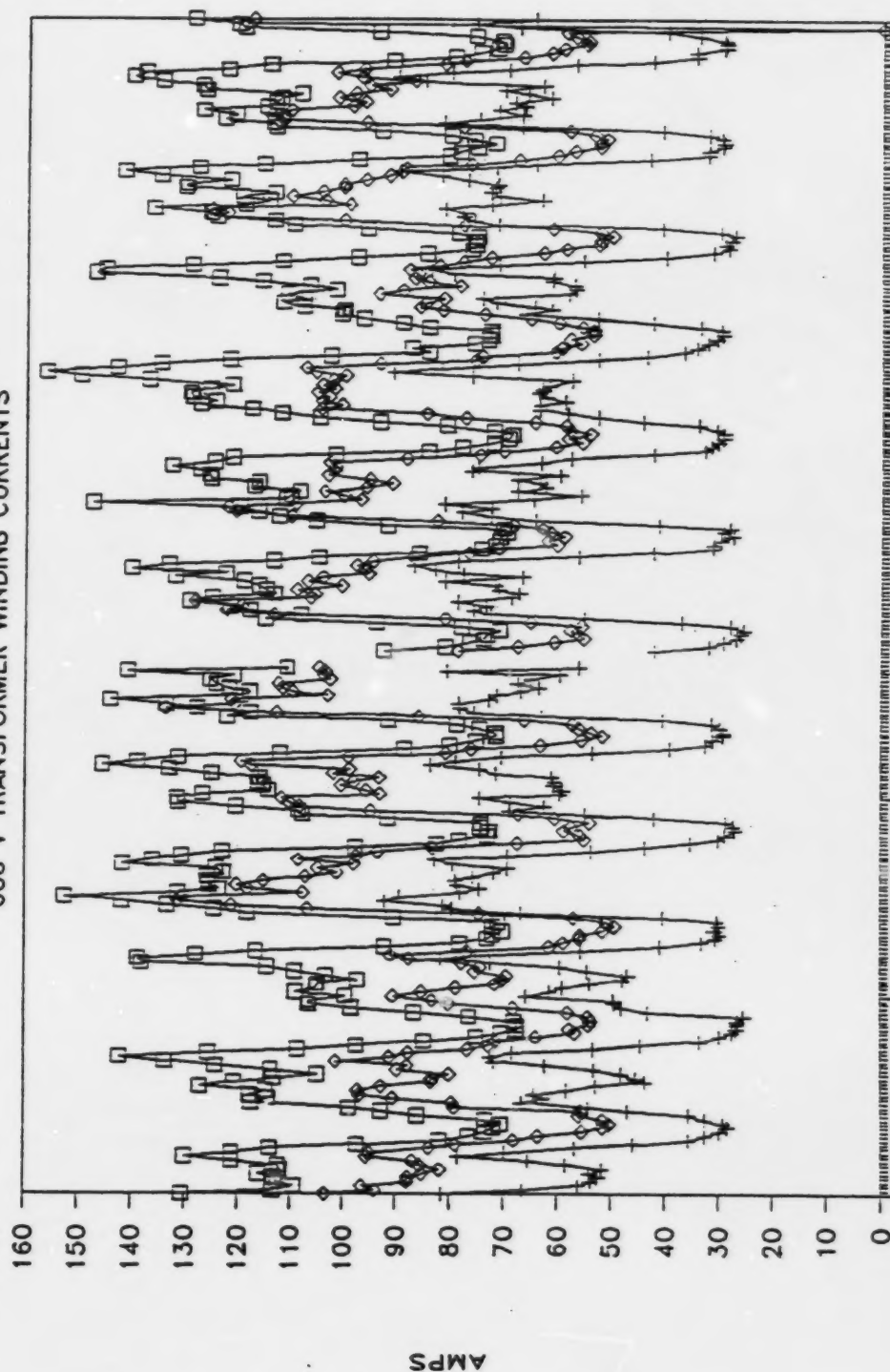
Figure C17



PERFORMANCE IMPROVEMENT BY THE REFLECTOR IS MOST EFFECTIVE DURING BRIGHT CLEAR DAYS AND IS LIMITED TO PERIODS WHEN THE GEOMETRY OF REFLECTOR MOUNTING MATCHES SOLAR POSITION.

BIG TROUT LAKE PV GENERATOR

600 V TRANSFORMER WINDING CURRENTS



19 SEP 86 21 SEP 86 23 SEP 86 25 SEP 86 27 SEP 86 29 SEP 86

SLIDE NUMBER 147

UNIT: AMP

SEP 86

basic applications.

EPRI is the Electric Power Research Institute financed by all the electric utility members across the U.S. and Canada. They have undertaken a number of serious photovoltaic investigation research projects which would be of interest to a lot of people.

FSEC is the Florida Solar Energy Center, located just at the south end of Cape Kennedy. If you're down that way, you'd be very interested to drop in and take a look at them. They'd be very helpful in showing you what they have. They have installations there where they're comparing the effects of tracking systems versus flat-plate fixed systems in one axis and two axes, and a number of systems for houses, utility-interconnected and battery-operated as well.

J.R.C. is the Joint Research Centre in Italy, run by the Commission of Economic Communities. They are doing extensive testing of photovoltaics in their lab. They qualify products for their demonstration programs and have roughly twenty professionals working in the area of PV.

NTIS is an institution that doesn't do anything itself other than disseminate information. It is more or less a focal point of the U.S. Research Information Distribution Centre, and any reports that you come across in the literature, et cetera, can normally be obtained through the NTIS.

O.M.E. is the Ontario Ministry of Energy. It has been involved in a number of research consulting project reports on photovoltaics, primarily in Canada.

SERI, Solar Energy Research Institute, located in Boulder, Colorado, are doing in-house research. They are issuing publications and they are a little more on the technical side, the research side, as opposed to some of the other groups.

At the bottom -- I've just shown one -- there is a data base available from NTIS if you have a computer hook-up. That is very expensive. That data base is available in Canada through CANOLE, which is the data base system organized by the CISTI, Canadian Institute for Scientific and Technical Information, in Ottawa. Your access to

NTIS is somewhat more economical through them than going direct.

---SLIDE NO. 61

Another very important source of information is periodicals. There have been a number of periodicals listed in the handout package that you received this morning published by the Florida Solar Energy Center. On that list, there are a number that have gone out of business, and this is more a corrected list.

Those that are no longer in operation are the Photovoltaics Electric magazine, the Renewable Energy News and the Solar Age. These, in particular, are no longer in publication.

Alternative Sources of Energy is the first one. I've brought a few sample ones just to show you. This is emerging as one of the better current magazines for giving you information on photovoltaic installations and current technology.

Energy: The International Journal is a technical journal of rather deep technical papers.

NTIS Energy is a publication put out weekly by the NTIS, which gives in detail an abstract of the various reports that have recently been published. You can subscribe to this service. This Energy periodical covers coal gas, nuclear, and also solar energy. Photovoltaics is included under the solar energy. It will keep you very busy keeping up to date tracking all those articles.

Photovoltaics International is one of the few dedicated journals to photovoltaics itself. It is published in the southwest and is very useful for technical and application-related information.

Progressive Builder, I have on the list as the successor to Solar Age and Renewable Energy News. It is, unfortunately, in my mind a very big disappointment in that the coverage of photovoltaics is almost minimal. I have it on there solely for the fact that it is the successor to the other publications, which were of considerable interest. Solar Age was the previous one, and I show it because there are some good articles in the past issues of this publication.

Sol is a publication put out by the Solar Energy Society of Canada, and it comes out, I think, six times a year. There are several issues that are related to photo-specific technologies. There is another one coming up on photovoltaics in the new year.

Solar Cells is an academic of publication, very detailed, primarily research-oriented on devices and what-not. Solar Energy is a publication put out by ISES, International Solar Energy Society.

Solar Energy Update is a publication that I find very interesting. You have to find out where it is available or you can subscribe to it. What it does is it publishes monthly, in detail, abstracts of articles in various publications throughout the world that are of interest to particular technologies.

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PV, for instance: We have the "application of solar cells" from Asian Institute of Technology in Bangkok, a solar-powered satellite concept, module and solar cells valued as a function of efficiency. You can find an abstract and where it's located.

---SLIDE NO. 63

Now, that comes out monthly, and then, once a year, they publish a summary, an index, of the articles and refer back to those monthly publications. You can see in here the extensive list of types of articles that they list: power supplies, power plans, a complete breakdown of articles dealing with photovoltaics.

---SLIDE NO. 64

In photovoltaics in particular, a great source of information is in the proceedings of conferences. There are two major international conferences held in the world: The IEEE Conference in the U.S. and the CEC Conference that we referred to being held next week in Spain. It is more or less oriented towards the European community. There is a third one, the PV SEC, which is an Asian conference which has had two meetings now. The third one is coming up in Kyoto, I believe, or in Tokyo next year.

The INTELEC Conference is one that has just concluded here in Toronto. They have proceedings with articles on PV. ISES, International Solar Energy Society, includes in their conferences the photovoltaic technology list.

---SLIDE NO. 65

I didn't bring samples of those, but there is one from the IEEE. Believe it or not, it's about 1700 pages and it's about this thick. It's an 8 1/2 by 11 document. It's a pretty hefty set, but extremely good articles in all phases of photovoltaics in those.

Newsletters: "Infosol" is put out by Energy, Mines and Resources, detailing information in Canada, primarily. "PV Insiders' Report" is a monthly newsletter which gives you commercial, economic, and technical information. "PV News" is another monthly newsletter put out by Paul Maycock, one of the noted consultants in the States. That comes out on a monthly basis as well.

"Solar Energy Intelligence Report" is another one detailing solar energy applications. It is very good for U.S. law and legislative developments.

---SLIDE NO. 66

I have listed the R and D bulletin from D.S.S. This publishes monthly. They list in there the contracts that have been awarded for the various government departments. This is a sample listing of one of the pages. You can see down here, "Ontario Research Foundation." Here, Low Power Photovoltaic Systems for Northern Applications has been awarded a contract by Energy, Mines and Resources in the amount of \$52,991. These are reports that come out which may be of interest to you.

Now, EPRI puts out publications such as this one on silicon photovoltaic cells and TPV conversions. This is the type of publication you get. It's very detailed, very documented, excellent material on specific topics on their research projects.

From the NTIS, you can get some of the U.S. publications, the D.O.E. "Five-Year Plan on Photovoltaic Energy Systems: A Program Summary for 1984" for

instance. It documents the contracts that have been let by the various government lead agencies, Sandia, JPL, who the contracts have gone to, and the work that's been done and the amount, et cetera.

A similar type document to that has been published in Canada under the "Contract Registry" title by NRC for the work that they were doing, and I understand that there is an intention of the EM&R to publish a similar document for the work that they are doing.

---SLIDE NO. 67

This is a sample of the NRC Project Summary Sheet. It describes the contract. It describes the documentation numbers, the contractor, the investigator, the project manager, the scientist, et cetera, and then, at the bottom, a brief description of the objectives and what is happening on the contract.

SERI puts out an article-type publication, "In Review," focusing primarily on their in-house work on photovoltaics, primarily research-oriented.

---SLIDE NO. 68

Then we move on to the manufacturers' literature as another prime source of information, and I've listed only three here. AEG put out a publication of interest to all who are using photovoltaics. It's primarily dedicated to photovoltaics. Arco Solar has put out publications. Solarex has put out publications. You can obtain copies of those from their representatives.

---SLIDE NO. 69

I mentioned design handbooks. There's one that you might find useful: "Photovoltaic Stand-Alone Systems Preliminary Engineering Design Handbook." Again, this one is available from NTIS and takes this type of format. You can get the number and write away and obtain those.

---SLIDE NO. 70

Rauschenbach has another design book that you may be interested in obtaining, although it is very technical. It also deals with the space applications if you have any interest in space applications.

---SLIDE NO. 71

The final source of information that I've listed is the standards group. We have two standards in publication at the present time on photovoltaics by the Canadian Standards Association. There's F380 on photovoltaic modules and F381, "Photovoltaic Power Conditioning Sub-Systems."

The IEC, International Electrotechnical Commission, is in the process of formulating documents pertaining to photovoltaics. There are no official documents published at this time. However, there are a number in the works and various drafts are available on specific subjects from the committee members.

The ASME and the IEEE in the States also are involved in promulgating standards in various photovoltaic technologies.

I wanted to go through this because I think that there is a lot of information out there that is available that people are not normally familiar with. I hope that what I've given you will help you in some respects in your search for information on photovoltaic technology.

PHOTOVOLTAIC APPLICATION SEMINAR OCTOBER 23, 1986

Royal York Hotel
Salon A Convention Floor

INFORMATION SOURCES - REPORTS

D.J. ADKINSON

Institutions:

AFME	Agence Francaise pour la Maitrise de l'Energie Val Bonne, France
Brace Research Institute	P.O. Box 900, MacDonald College Ste Anne de Bellevue, Quebec H0X 1C0
EPRI	Electric Power Research Institute 3412 Hillview Avenue Palo Alto, California 94304
FSEC	Florida Solar Energy Center 300 State Road 401 Cape Canaveral, Fl. 32920
JRC	ISPRA Establishment 1-21020 Ispra (Varese) Italy
NTIS	National Technical Information Service 5285 Port Royal Road Springfield, VA. 22161
OME	Ontario Ministry of Energy 12th Floor, 56 Wellesley St. West Toronto, Ontario
SERI	Solar Energy Research Institute 1617 Cole Blvd. Golden, CO 80401

Data Bases:

NTIS via CAN/OLE

Publications Section
Canada Institute for Scientific & Technical
Information
National Research Council Canada
Ottawa, Canada K1A 0S2

SLIDE NUMBER 60

periodicals:

Alternative Sources of Energy (ASE)
Alternative Sources of Energy, Inc.
107 S. Central Ave.
Milaca, MN 56353
Energy: The International Journal
The International
Pergamon Press, Maxwell House
Fairview Park, Elmsford, NY 10523

NTIS Energy

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161

Photovoltaics International

Photovoltaics International
2250 North 16th St., Suite 103
Phoenix, AZ 85006

Progressive Builder (Solar Age, REN)

Progressive Builder
Subscription Services
P.O. Box 985, Farmingdale, NY 11737-9685

SOL

The Solar Energy Society of Canada Inc.
Suite 206-135 York Street
Ottawa, Ontario K1N 5T4

Solar Cells

Solar Cells
Elsevier Sequoia, S.A., P.O. Box 851
1001 Lausanne 1, Switzerland or,
Vanderbilt Ave., N.Y., NY 10017

Solar Energy (ISIS)

Solar Energy
Pergamon Press, Maxwell House
Fairview Park, Elmsford, NY 10523

Solar Energy Update (NTIS)

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161

SLIDE NUMBER 61

GOVERNMENT PROGRAMS - MR. LARRY McCLUNG

(Mr. McClung is the technical co-ordinator for PV in the Solar Energy Division, Energy Mines and Resources, Ottawa, Ontario.)

I'm very pleased to appear here this morning as the representative of one of the companies or groups that's paying for this. It's very gratifying to see that there's a strong interest in photovoltaic applications in Canada, and I trust this interest will continue to grow.

You have heard this morning about many of the appropriate applications of photovoltaics. You have heard that photovoltaics makes sense in Canada and, I think, by implication, just about anywhere else in the world.

We at EM&R believe that it does make a lot of sense in many applications and we, like many of the speakers who were up here this morning but maybe didn't mention it yet, believe that there is a much stronger future for it, that there will be more and more applications which will make economic sense, that installations will become larger, more reliable, more cost-effective.

To that end, we operate some programs that we hope will help to make photovoltaics more accessible to the commercial, industrial, and private consumers. We essentially have three areas that we are working on.

First of all, there is research and development. That is where the bulk of our funds go, supporting research and development. It is the background work that happens before anything hits the market.

We are also involved in supporting technology demonstrations. Photovoltaics is an innovative technology. It's beginning to lose the term "new." I hope it has certainly lost the feeling that it's unreliable and a little bit flighty. In fact, its main selling point is its extreme reliability. It is innovative, so there are new demonstrations of new types of systems, of particularly effective systems, and we'll help to support them.

The third task is technology transfer and you're seeing

an example of that today. EM&R's purpose in supporting these three activities is to facilitate the development and implementation of photovoltaic devices and systems which will meet the twin goals of technical and economic viability, both of which must be met if photovoltaic generators are to become even more widely used in the future economy.

I should mention that I'm supposed to be addressing general government programs. There are no other specific government programs within Canada that I am aware of. I am fairly new to the government, so I hope I'm not stepping on anyone's toes by not mentioning them.

However, EM&R has signed memorandums of understanding, a nice little term, with several provinces, which essentially commit them and us to work together on many types of projects. Most of them cover more than just photovoltaics but all kinds of renewable energy projects, so there is support from the provincial governments. We appreciate that because it makes our dollars go farther. It also helps to convince us that more than just the federal government has an interest in this.

In the R and D focus of our program, we are primarily looking for R and D related to the development of appropriate systems and components for use on off-grid locations within Canada.

You have heard very little about utility-interactive systems this morning and, I think, rightly so. It has been deemed that the most economic systems are those where, essentially, cheap, abundant electrical power is not readily available. We're looking at remote sites. We're looking at applications within Canada.

We currently support twenty-one active contracts. The average value of those is about \$45,000. It ranges from quite small to fairly large. Forty-five thousand dollars per year, I should say, and some of them last for several years.

Typical guidelines: We will support up to a hundred percent funding on R and D contracts. However, in general, if we're looking at R and D which is aimed at product and device system development and is sponsored by a private company, our maximum feeling is seventy-five percent funding.

We will be issuing a request for proposals in mid-December because we expect to be funding a number of new projects in the new fiscal year. If any of you are interested, there will be an announcement in the D.S.S. bulletin in December and you can get copies of the R.F.P. We are, I think, interested in hearing the ideas of new players as well as the many of you here who have already been doing work in this area.

Now, the R and D program is not directly applications-oriented and it consists of a number of highly specific projects, so what I'm going to do is just give you a very short summary of two or three of them so that you perhaps get a flavour for what we're doing.

One of the projects that we are supporting now is an installation of a photovoltaic-gasoline generator hybrid system in Trout Lake, Northwest Territories. That system has just been installed and is essentially operational except that the building is not finished, according to the last I heard, so no one's moved in and no one's using any power.

That is a system which is just north of 60 degrees latitude. It has about a 675-watt array, and I believe that that is expected to contribute about twenty-five percent of the seasonal load, and it's something which is deemed to be fairly attractive. It's completely automatic, the transition between the PV and the gasoline generator, so that the person who is turning on the light switches or the fans or whatever else doesn't really know where his power is coming from.

That particular system has some extensive monitoring going on so that we'll know how it performs, what the reliability is, whether we're getting the power outputs predicted.

Another example of specific product development is a small company on the west coast. We are funding them to design a small battery-charge controller. It will handle up to about eighty amps, and they're projecting that they will be able to sell it for a few hundred dollars in reasonable production quantities.

This is something where it's going to be a modular unit. You have a 20-amp system: you buy one for twenty amps.

You have an 80-amp system; you buy one for eighty amps; but it's essentially the same box, the same control equipment, and it will perform all the necessary duties in order to keep your batteries from being discharged severely or from being overcharged. With proper communication, they can tell you when the state of charge in the batteries is getting too low and you need to do something else.

We're also supporting some work related to batteries, which is seen as the weak point in many stand-alone applications from a reliability point of view. The batteries have been around for years and everyone knows how they work, but we're putting them under some new stresses in this cold weather and rather strange cycling, so currently, although we're not funding fundamental research on batteries, we are funding a survey of people's experiences with batteries in Canada in photo-voltaic applications.

We're also funding some testing of batteries, which, essentially, is simulating batteries going to an arctic winter at a very slow discharge over several weeks to see how they perform because that type of data is usually not as readily available from battery manufacturers. If you ask them for the hundred-day characteristics at minus 40 degrees C, they will give you a blank stare.

We're also funding some work to begin developing what we hope will become a CSA standard on batteries for photo-voltaic applications.

In the demonstration side of the work, this work is the responsibility of the special projects group within the Ener-demo program. The mandate of this program is to support innovative projects that hold promise for significant contribution to the development of photo-voltaics and other solar energies with the objective of accelerating the adoption and commercial use of these technologies, as well as to increase the awareness of the public and commercial sectors of the opportunities for utilization.

For those of you in the telecommunications industry, this program may be of more immediate interest if you're seeking money in your pocket or in your company's pocket. It is essentially designed to take an application which makes sense, is technically feasible, is at least near

economic feasibility, but is new and innovative. It hasn't been tried or it hasn't been tried in Canada. We will fund part of that program, basically, to help share the risk.

If people within your company say it makes sense, all the paper says that it's economically feasible, that it's technically feasible, but there's this little fuzzy, "But, gee, guys, it's kind of new," we would like to help you get over that, so we will fund up to seventy-five percent of the capital costs of the project.

Typically, funding levels, I should mention, are about half of that seventy-five percent. In other words, we're finding that people don't need three-quarter funding in order to be convinced to go ahead. In fact, I believe there are some programs that we're only funding perhaps ten to fifteen percent of the total project cost, and that's enough to make people decide that it's worthwhile.

We currently have six active projects in this area. By "active," I mean either the contract was signed yesterday, someone's starting to dig some dirt, perhaps the system is being installed, or perhaps the system was installed a year or two ago and we're still supporting the monitoring of that system.

These range in application. There's going to be a grid-interactive house in Mississauga with a 5-kilowatt array up on the roof, which will be sort of a showcase and a demonstration of how that type of grid-interactive technology works.

There's an interesting project out in B.C. where we're pumping water to water the range where cattle are grazing. It's a dry area. There is water available at the bottom of the hill and they pump it up to the top of the hill.

Also, we're funding work on a stand-alone street lighting device. It's essentially a street light similar to what you'll find in many highways and parking lots, but it doesn't need to be connected to the grid. This has interesting applications along many highways or remote areas where it just gets expensive to string the extra two or three hundred yards of wire.

We're also funding a program you'll probably hear a

little bit more of this afternoon with B.C. Tel on Calvert Island, which is a combination wind-diesel-PV hybrid system. One of the presenters this afternoon, I'm sure, will get you much better acquainted with that one.

The largest installation in Canada at the moment is a 10-kilowatt PV system in Big Trout Lake, northern Ontario, run by Ontario Hydro. That system has just gone on-line, I believe, within the past month. It seems like it was just yesterday. The time has been going by. So far, it has been working like a charm, and its essential purpose is to reduce fuel consumption because it was a localized diesel generator grid, and the diesel consumption is now being reduced. Again, we're monitoring that to see what are the economics of that installation.

There's also a hunting and fishing lodge in northern Ontario which used to have a diesel running twenty-four hours a day. I think we've now got it down to running about ten hours a week because the PV system and batteries were added. The PV system is charging the batteries most of the time. The diesel does not come on very often and the people are enjoying the quiet and the economics. They're expecting about a five to six year pay-back on that project.

Technology transfer is something that we believe is important. In today's world, it seems that the only measure of success is dollars. Regardless of how technically feasible what we're doing is that just won't cut it in the end. If things don't get into the marketplace, if money is not being generated and passed from hand to hand, things aren't considered a success.

Therefore, the only way that we can make our photovoltaic support program a success is, in some way, to convince industry and consumers to take our pilot projects, to take the products which we've helped to develop through our funding, and apply them many dozens of times, many thousands of times. To that end, we support various activities in technology transfer.

At the research end, we make available many of the file reports on our research papers. We will publish them and make them generally available. We also have plans to bring together the key researchers that we're supporting under contracts, probably on an annual basis, for.

essentially, a workshop of contractors where they can report to each other what research they've been doing, what results they've had, what difficulties they've had, and it will be an open forum where people can discuss what's going on.

We're also trying to educate the public. One of our main efforts to this end at the moment is we're putting together a PV buyer's guide. This is going to be a thirty or forty page booklet that will be primarily aimed at the private consumer. It will have a focus toward residential applications.

We feel that these are some of the less educated users. The commercial industrial users tend to get educated more quickly to technological development. This should hit the streets sometime next summer, and we hope that it will be a boost to the cottage and remote-housing uses of PV systems.

We also have several short publications, fact sheets, and summaries of projects, which are available on a requested basis, to tell of some of the successes.

As in all R and D, there are some that just lead to dead ends. We accept that and we're going to continue to accept it, but it's not part of our technology transfer program.

Then there's the technology transfer to industry and commercial users. This seminar is one of the examples of that. We fully expect that there will be more seminars along this line.

I would ask you to take seriously Don's request earlier this morning to fill out the evaluation sheets. We've seen from the registration that there's a lot of interest. We'd like to get your opinions at the end of the day as to whether the format was appropriate. Is the information at the right level? Do you think that this should be repeated yearly, every six months, every week, once every twenty years?

That type of feedback, either through those forms or directly through our office, will help us in determining how useful this particular forum is and how useful future ones should be, and we would very much appreciate your feedback on that point.

With that, I will conclude my talk. I would suggest that, if you have questions, phone me when I get back to the office or talk to me today. I realize that there may be some interest in the government program. My goal is to make the PV program in Canada as good as it can be, and the only way that can happen is with the widest support from industry and consumers that we can possibly generate. Thank you.

PLANNING A PV PROJECT - MR. BRIAN LOSIE

(Mr. Losie is in the Power Engineering division of B.C. Tel, the major communications company in British Columbia Canada)

---SLIDE NO. 72

I'd like to start out first of all with a bit of a statement on salesmanship in the form of a cartoon that I don't know if you can all read from the back of the hall there or not. It kind of tells a bit of a tale which I think we have to try and collectively overcome.

---SLIDE NO. 73

We've got several applications for the use of photo-voltaics in conjunction with telecommunications in B.C. I've kind of broken them down into three categories, the first one being small UHF-VHF repeater stations. These are typically marine or land mobile radio telephone channels, and they are situated, as a rule, in remote locations to provide coverage of the many coastal inlets and waterways of B.C.

---SLIDE NO. 74

There's no commercial AC source available, and typically, the systems were powered using caustic potash batteries.

---SLIDE NO. 75

This is our modus operandi for getting them to site each year. We'd fly them in in a reinforced fibreglass box containing about thirty-three cells at about \$100 apiece, and this left us with an annual charge of about seven or eight thousand dollars.

The typical peak load at these sites is around fifty watts in an average duty cycle of about ten percent.

---SLIDE NO. 76

We then size the solar array using the peak-hour technique that was described a little bit earlier. I'll go over it briefly. This is a system whereby the total daily insolation is calculated from Environment Canada data and it's divided by a factor of eighty-six langleys per hour, which correlates to the peak rating of the solar panels.

This gives us a figure for peak daily hours of sunlight, which, when multiplied by the peak current of the panel, determines the number of amp-hours per day the panel will produce. Dividing the daily load by the panel's output determines the number of panels required.

Safety factors to compensate for weather variability as well as battery recharge efficiencies are also applied. As a typical rule of thumb, we require four panels per radio channel.

---SLIDE NO. 77

The battery, and I'll speak briefly about it, is specifically designed for photovoltaic applications or shallow-discharge applications, where "shallow discharge" is defined as no more than twenty percent of the battery capacity being removed per day or per cycle, and we size the battery to provide us with twenty days autonomy.

The selection of the type of battery has recently been affected by D.O.T. regulations relating to the transportation of hazardous goods in aircraft. We are now using a sealed battery in these applications, a so-called "maintenance-free" type.

Currently, we have seventeen sites of this nature in B.C., twelve of which are in my area of responsibility on the coast. The economics of this system: A typical installed system costs around \$20,000, which results in about a three-year pay-back on capital investment.

---SLIDE NO. 78

The second type of system that we use is what we call a small-cycle charge system. This is typically for radio loads of up to four hundred watts. We historically used thermo-electric generators but we found them not practical due to the logistics of refuelling propane tank

farms located at helicopter-access sites.

The original concept here was to install one diesel generator and a battery and operate in a charge-discharge mode with the diesel operating approximately one day in three. Subsequently, a solar array was sized to extend the diesel operating cycle to one day in six, and we have economically evaluated that.

Just to give you some numbers, the array output -- it's a sixteen-panel array, and its average output is ninety-two amp-hours per day, and our load requirement is a hundred thirty-eight amp-hours per day. The difference of those two over a five-day period results in a cumulative discharge of two hundred thirty amp-hours out of the battery, so we have about a thousand amp-hour battery, which keeps us within the twenty percent of the shallow cycling.

---SLIDE NO. 79

The economic advantage of this is primarily in fuel savings. At a cost estimated at ten dollars a gallon delivered to site for helicopter-access sites, we stand to save about \$4800 per year with the addition of the PV system.

I should explain, in this slide, there's a power cable in the background. This building where it's situated now isn't where it was finally installed. We didn't have power in the area. This is in a test mode in one of our towns on Vancouver Island.

Other advantages of the addition of the PV is that it reduces the maintenance of the diesel and the frequency of engine replacements and it gives us an increased measure of redundancy should the engine fail.

Featured on the array was an adjustable tilt angle that was incorporated to accommodate winter-summer settings, and it provided it with two benefits. First of all, of course, it sheds snow in the winter more effectively, and it optimizes the array output in the summer when the traffic on the radio channels is higher.

The estimated pay-back on the solar panel addition is about four years. At the present, this is the only site we have in operation in this mode, and it was put in

service in 1984.

---SLIDE NO. 80

The third type of system I'd like to discuss is the wind generator-PV-diesel hybrid. It's primarily designed for systems over four hundred watts and is dependent on the wind regime in the area, of course.

The typical duty cycle of the diesel in the wind-diesel hybrid is about twenty-five percent, and this improves to about ten to twelve percent with the addition of the photovoltaic array.

The wind-PV system is a very complementary system. In the wintertime, in our locations, we get periods of very high winds but, of course, low sunlight levels, and conversely, in the summertime, we have periods of low wind but good solar insolation.

The PV array was sized to double the discharge period in the summer, assuming no contributions from the wind generators. This site also features adjustable support structures to provide maximum energy absorption in summer and to shed the snow in the winter. We also, again, provide a measure of redundancy in the winter should the wind generators fail. We get good production in the winter due to high reflectance off of the snow.

---SLIDE NO. 81

This is a bit of an experiment that we did where we insulated the back of half of the array just to see if it would inhibit the ice build-up, but the jury is still out. It wasn't really too successful an attempt.

---SLIDE NO. 82

This particular day, I was flying past the site of that array I just showed you, going on to another radio site. We had two maintenance personnel on site. I got on the radio to them and I asked what the output of the array was, and it was rated at 1200 peak watts, and we were getting two hundred watts out of it on that day, so I was fairly pleased with the operation of it at that point.

---SLIDE NO. 83

The company is embarking on a demonstration project this year in conjunction with Energy, Mines and Resources to repower an existing radio site.

---SLIDE NO. 84

This site presently operates in a three-diesel prime power system, and the engines consume over 15,000 gallons of fuel per year to service radio and domestic loads. It's maintained by a caretaker couple who live in quarters below the radio site.

---SLIDE NO. 85

We considered, basically, four alternatives to the existing system. You can't quite see it on the slide, but on the right-hand side about halfway up, it's a bit of a sandy beach, and that's where the location of the house and the powerhouse is, and there's a high-voltage line running up the hill to the radio site.

---SLIDE NO. 86

The first option was to install a down-sized prime power site, putting in a new prime power system at the top of the hilltop radio site and decommission the lower, domestic site and powerhouse.

The economic analysis we performed was present worth of annual charges or life-cycle costing. That basically determines how much money is to be invested in today's dollars to operate a plan for fifteen years or an indefinite study period. It considers both first cost as well as maintenance charges and it provides an accurate comparison of two or more systems in economics in today's dollars.

The present worth of the first plan, the new prime power system was 1.6 million dollars. This system is a proven technology and it's highly reliable. However, the fuel costs and maintenance costs are prohibitively high.

The second option was a cycle-charge system consisting of two diesels. The first system we put in was a single-diesel site. This would be a two-diesel because of the nature of the radio system we're working to.

It consists of two diesels operating in a charge-discharge configuration with the battery plant. The duty cycle in the diesel plant is calculated at about thirty-three percent, resulting in a present worth on this system of 1.1 million dollars. It's a fairly reliable system but it results in reduced battery life.

The third plan was to incorporate a wind-diesel hybrid at the site, where primary site power would be generated by two 2-kilowatt wind generators connected to the station battery. The diesel would be called upon to start and recharge the battery when winds are light or building requires heat.

The duty cycle on the diesel system is estimated at twenty-five percent, and this system would be the least reliable in terms of redundancy. However, the fuel costs are low. The present worth of the system is \$958,000.

The final system evaluated was the wind-PV-diesel system, whereby a solar array is added to the Plan C to produce power in the summertime when winds are light. The added redundancy increases the system's reliability and the fuel consumption is further reduced. The duty cycle on the diesel in this option would be about ten percent.

This system would have the highest initial capital cost, but it has the lowest annual charges. The present worth of this system is \$918,000.

We will also be incorporating the use of a microprocess-based datalogger controller at this site to increase the system's efficiency and to quantitize the data related to energy production. The device will sample, process, and store data for solar insolation, wind speed, generator outputs, building temperature, and battery voltage, as well as control the operation of the diesel, primary building heaters, and auxiliary loads.

---SLIDE NO. 87

In closing, it's expected that we'll be increasing the implementation of alternate energy systems in B.C. Tel to supplant prime power systems presently in operation as new solid-state digital radio systems replace existing radio systems and reduce demand.

I'd like to thank you for your attention, and I'll be

pleased to answer any questions relating to our systems
during the question-and-answer period at the end.

SELECTING A PV BATTERY - A SIMPLE TASK? -

DR. KLAUS TOMANTSCHGER

(Dr. Tomantschger is Manager, Technology Development of Astris Inc., a Mississauga, Ontario company involved with energy storage and fuel cells)

I think my voice is loud enough that I can step over here and basically talk a little bit about what does the battery do with the PV system, what are the restrictions, and what are the size requirements on there.

---SLIDE NO. 88

Now, if you do a cost-effectiveness analysis of power systems, you will find that photovoltaic power systems, including the battery storage, depending on the remoteness and load size, will satisfy quite a variety of needs economically today.

The systems they are competing with right now are the primary batteries, which can lead to a cycle-charge diesel system, and if you're very close with the utility grid and you need a large load size or power off the load, it will be most economical to connect it to the grid.

Now, as Don mentioned, I've been working in product development and in fuel cell development for the past three years, and if you do your analysis as we have done, you will find out that the fuel cell is really entering the picture and, in particular, challenging the diesel system.

Our company will offer fuel cell products of a power size of less than a hundred watts next year, and we will be in the 2- to 10-kilowatt range two years down the road.

We go with the fuel cell directly from the energy of the fuel into a grid at the efficiency of 60 percent, which means we will, with the fuel cell have an efficiency of about three times to five times that of a gasoline or diesel generator.

---SLIDE NO. 89

Now, if we ask ourselves what kind of batteries do we really need or use in electrical storage applications in PV systems, you really have to take into consideration the power size of the load and the variety of systems available today.

Now, if you look at those systems here, basically, over several magnitudes of power, this assembly with lead-acid batteries will satisfy the needs of the low-power and the hybrid, completely sealed, maintenance-free systems.

I will concentrate most of the performance data which I'm going to present in the forum on the lead-acid system. Always have in mind that the trend will be the same. I will also have a brief comparison of those two systems in particular.

Now, if you look ahead, those two systems are the ones which are used presently. I can give you hope that the battery man is working on it. We know that the battery is very often limiting the capability of the PV system right now, and one of the systems to watch out for is the nickel hydrogen, which is really not a new system. It's traditionally been used in space applications in PV systems on satellites because the nickel hydrogen has a tremendous cycle life.

Another system to watch out for in the future is open-flow systems, and I will be talking a little bit about those systems because it's a move away from the storage battery where you have the energy chemically stored on the plate. You move into a system where you have an electrochemical generator and you have the excess mass that you want stored in the tank.

This brings unique characteristics to the photovoltaic use, especially if you want to design a system, for example, for the arctic, where you want to increase the capacity but you don't want to increase the power, because the power requirement of the load is going to be roughly the same.

Let's ask ourselves what are the parameters influencing the size of a battery? The first one will be the power requirement of the load. Let me, for the rest of the day, just assume that the load I am using is a constant

load, and we both know in many cases it is not.

Battery discharge characteristics for that load requirement will greatly influence the size and the performance of the battery. Important factors to watch out for are the depth of discharge and the operating amperage at the depth location.

You now know roughly what kind of battery size you have. You want to do the next step and size the PV array, which will, of course, depend on the climatic conditions, but please don't overlook that the battery energy efficiency and charge acceptance will have a major impact on the sizing of the PV array.

Now, if you come up with a system like that, you can get a pretty good idea, after you're through with your sizing, what's going to be the operating and maintenance schedule. What is your expected lifetime going to be like?

---SLIDE NO. 90

Now, let's start out on the battery discharge characteristics. You see here the available capacity is a function of the temperature for a lead-acid PV battery. You see that, by going from a temperature of about 20 degrees centigrade to about minus 20 degrees centigrade, depending on the load conditions, you would typically have a reduction in available discharge capacity to fifty percent of the original value.

Now, if you go on a low discharge -- for example, a five-hour rate -- this steep fall will not be as pronounced as, for example, the eight-hour rate, which would be a higher discharge. Those specs should be provided by the battery manufacturer.

Also, when you are sizing your batteries, please have in mind that, over the life cycle of the battery, the discharge capacity changes, and in fact, if you look at the nominal capacity of a hundred percent, it's in its early cycle life. The end of the life is generally defined as the point where the battery is unable to maintain eighty percent of its rated capacity, so that's really the capacity you are aiming at because you have to anticipate that you want to supply your load at the end of the battery life as well.

---SLIDE NO. 91

Now, I've done some studies a couple of years ago, simply caused by the fact that people are throwing around cycle life data, and that really doesn't mean much if they are not defined. In fact, the cycle life has a semi-logarithmic relationship with the depth of discharge, so cycle life data obtain that.

The question I was asking myself was, for a variety of applications, if you cycle a battery down to various depths of discharges and you add up the capacity you can get on every discharge, you can generate something which is called "cumulative capacity." What you want to do is get the maximum energy throughput of a battery within its useful lifetime.

If you do your calculations, and we have published data on that, you will find out that, for example, for a PV lead-acid battery, which is shown here, you will best operate it at between thirty and fifty percent depth of discharge because then your energy throughput in kilowatt hours per kilogram of battery is going to be optimum.

Now, the battery designer can build features into the batteries in order to somewhat change that. For example, a sulfur battery will be designed differently than a deep-discharge battery, and we therefore have a peak somewhere in the ten to fifteen percent depth of discharge area. Now, again, a unique feature of the flow battery is that it's the only real deep-discharge battery, if you want, that is available today.

Let me use the zinc bromine here as an example to show you what I mean. If you want to get ninety percent of your optimum energy throughput within your cycle life, you can operate this battery at between forty and a hundred percent depth of discharge. You see that, for a kilogram of battery, you get an awful lot more as compared to the other systems available.

---SLIDE NO. 92

Now, something which has been often overlooked is the effect of operating temperature on the cycle life of the battery. This is a deep-discharge battery which has been cycled under similar conditions at different

temperatures. As you go from 30 degrees centigrade to 50 degrees centigrade, which is not an exotic temperature, you see that the cycle life will drop from five hundred to a hundred hours under the conditions used.

The message I am trying to get across here is, if you use storage batteries, do everything you can to maintain them above freezing or you will have tremendous problems in the maintenance and in the life of the prospective battery.

---SLIDE NO. 93

Now, let's go to charging a battery. I won't go into the graphs which Brian and Eric showed this morning relating to how to calculate what the sun is doing. I'm somewhat lazy and define the "constant sun," which you switch on in the morning at 8:00, has constant power until 4:00 in the afternoon, and then you switch it off again -- no clouds in the sky, no formula, nothing.

Now, if you have a battery which has lighted loads overnight, it will be at discharge state when the sun comes up in the morning. Now, we just look at the PV array and forget about power of the PV array, which now will operate the loads for the rest of the day. You will have the array producing power and the battery will be able to accept the power.

This is the working profile at different temperatures. Let's look at the 28 degrees centigrade curve. In the beginning, the battery will be accepting all the power the PV array is supplying, and, in fact, the count will remain pretty constant. The voltage of the battery will rise to a certain point. This is for a 96-volt battery because I've done most of the work on this voltage battery.

Now, you have reached a point in voltage where gassing occurs, and to avoid excessive gas, you have to reduce the voltage. We work, basically, with a constant voltage profile, and your count is going to go down.

Now, up to this point, you have been fully utilizing the photovoltaic array. From this point on, because you don't need the full power the photovoltaic array can produce anymore, you're really not utilizing what the photovoltaic array can do.

Now, if you go on in this way, after the count has dropped down to the point where the battery is fully recharged, occasionally, you would want to enter the gassing phase to destratify the electrolytes.

As you see, the curves for the different temperatures vary very much. What it boils down to is, very simply, the lower graph, depending on the operating temperature, you have a different end-of-charge voltage.

This one has to be available from the manufacturer, and you also have to be careful. There are really two end-of-charge voltages. The one that is shown here is including the gassing here, which would be the sun switch-off situation. In the real world, you will have a floating type charge, so you will have, generally, a floating type charge which is somewhat lower than for the end of charge.

---SLIDE NO. 94

Now, we've extensively studied the effects of low temperature on battery behaviour. One of the things you have to have in mind is the water loss or the gassing rate, if you want, during the charging -- of a 96-volt battery again -- over a temperature range, and you see that, at lower temperatures, the water loss is tremendous.

There's only one way to get around it. You have to put a combination system on there because an automatic watering system is likely to fail at minus 20 degrees centigrade.

---SLIDE NO. 95

Now, we've heard today already some talk about efficiencies, and what you really have to have in mind, now that you know what the size of the batteries are and you want to know the size of the PV array, is the energy efficiency.

The dash line here shows the energy efficiency of the typical lead-acid battery. You see, typically, the fifty to eighty percent area. What that means is that, if you operate at minus 20 degrees centigrade, as I say, you have removed a hundred watt hours off the battery during the night to supply the load.

At the low temperature, the solar panel will have to supply two hundred watt hours to bring the battery back into the same state of charge again.

It's a somewhat higher temperature here. For a hundred watt hours you remove, you will have to put a hundred twenty watt hours back in.

I designed five years ago an electrolyte destratification device which pushes up this curve significantly. We found, at the time, the cycle life of that battery was probably twice as much as the original battery.

---SLIDE NO. 96

Now, in many instances, what you will need is a multi-module battery because the PV module is not going to be able to supply the load. In that case, you have to be very careful because an additional parameter has to enter your thinking, which is matching of modules.

What you see here on the lower graph is the voltage profile of the 16-module battery during discharge. Of course, in our case, it was individually voltage controlled per module. If the first module -- in this case, number one -- hits the 5.1 voltage -- it's a six-point module -- end-of-discharge point, you switch off the total battery pack and you go into the charge mode.

Now, if you could add up the individual voltages and basically measure the permanent voltage of your entire battery pack, you say, "Well, I don't really need a monitor in the individual modules because they are fairly close, anyway."

However, if you pick batteries off the shelf, you're very likely to end up with a situation as you see here, which is an unmatched battery pack, where you have one module at the end of discharge but several others quite far away, which means the battery modules have different individual capacities.

Now, what you create is a situation where you have a battery and sixteen little power supplies which add up the energy which you really take out of the terminal of the battery. You would go on now, because the total voltage is more than compensated for by those good

modules as compared to this and you think you are really not close to the end of discharge yet, and you keep on going, and what's happening now is fifteen little power supplies are adding up to the total system.

This one switches around. In fact, it has not been removed; it has been replaced by a load resistor, and if you go on discharging that battery, in fact, you will get less energy out at the terminus with that module in as compared to if you remove the module. I'm not saying replace it. It is still in there.

---SLIDE NO. 98

Now, that brings me to the auxiliary battery equipment. I think a temperature-corrected voltage regulator is advisable. If you have in mind the end-of-charge voltage as a function of operating temperature, you really have to put a little temperature sensor in one of the batteries and correct for the voltage which the battery sees accordingly.

Now, under voltage protection, individual monitors are extremely helpful to reduce your maintenance and increase the life cycle. What they really do is show you that, in cold conditions, it's better to split up the energy, not only the charging energy but all the heat that's generated at the same time, provided you can do it.

Water-replenishing devices in low-temperature conditions, you basically cannot do without, and an electrolyte destratification can be very helpful in obtaining good cycle life and also, if the battery has to go through long periods of partly discharged condition.

---SLIDE NO. 99

Now, what you see here is basically what the batteries should look like. A replenishing system has to be on there because, with time, active mass will fall off and will show up at the bottom, and it will be extremely bad for you.

Now, the nickel cadmium will have similar trends. It's better at lower temperatures; it's a lot worse at higher temperatures. Nickel cadmium has a higher energy density but higher cost.

---SLIDE NO. 100

Now, depending on the daily discharge conditions and how often anywhere that you have days without sunlight, you will get a certain cycle of maintenance and also expected lifetime. I have a handout of this slide. If you give me your business card, I will put it in the mail.

---SLIDE NO. 101

Now, at this time, I have to bring you back to the real world, abandon my "constant sun" approach, and look at what will happen over the seasons to the sunlight. If you now have a battery which is sized properly for the sunlight, the state of charge of the battery over the season will look like that, which means that, over most of the year, it will be in the partly discharged state.

You can compensate for that by putting the PV array on and pushing the average state of charge up or by an electrolyte destratification device, where you separate the electrolytes to maintain a constant electrolyte gravity.

---SLIDE NO. 102

You are very frequently in the position, if you have the same load and you want to put a station up in the arctic, the power requirements of the battery remain the same, but for a variety of reasons, the capacity of the battery needs to be changed. If you have a lead-acid or a nickel cadmium storage battery, the only way to do it is by putting in three times the capacity. You buy three times as many modules and you will have three times the cost.

Now, with the flow battery, again, you have no consumable electrodes in the cell. You have collective mass in liquid form in the tank, which means the cost will not rise proportionally.

The ultimate system is really the fuel cell, which is like a diesel generator. Depending on the fuel and the size of the fuel tank, you can get an idea of how long the system is going to work.

---SLIDE NO. 103

Now, to give you a better impression, I brought a battery along which was developed at Exxon on this continent, and there's a company in Austria now building it, and I've just been there this summer. It's a zinc bromide system ten kilowatts, with 50-kilowatt peak rated system, and here, you have a twenty kilowatt hour zinc tank and a twenty kilowatt hour bromine tank.

---SLIDE NO. 104

Finally, here is 2 1/2-kilowatt fuel cell. You have the air intake like you would have the diesel. It's an ambient-temperature system, and there, you see the hydrogen tanks which supply the fuel to the fuel cell.

---SLIDE NO. 105

Now, let me finally say the nickel cadmium and lead-acid batteries can serve a variety of electrical storage needs in photovoltaic systems. New trends to look out for or have in mind are nickel hydrogen and flow batteries like zinc bromine, zinc chlorine, and iron chromium.

If you want to have a power system life cycle cost analysis, you will find out that fuel cells have a significant potential to penetrate the remote power station market. Thank you very much.

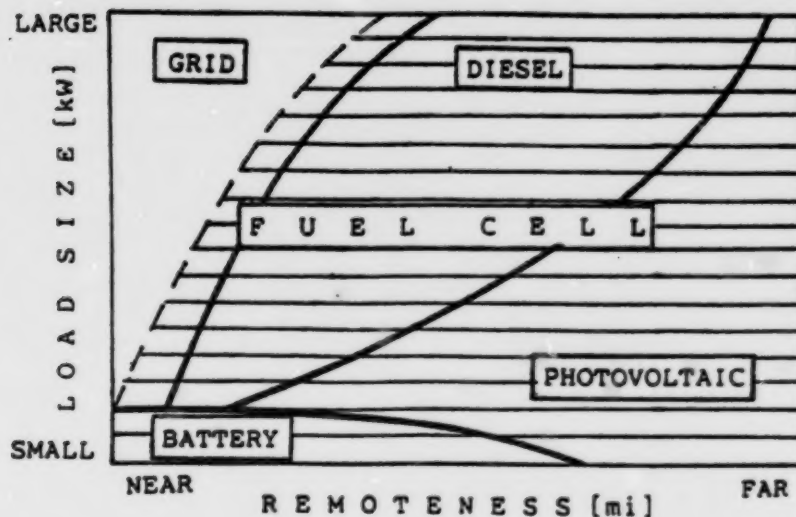


Figure 1: Cost Effectiveness Comparison Between Power Systems for Different Applications [1].

APPLICATION OF BATTERIES IN PHOTOVOLTAIC SYSTEMS

Power Scale	Sealed Cells				Vented Ni/Cd	Lead-Acid	Ni/H ₂	Zn/Br
	Button Type		Sintered Ni/Cd	Maintenance Free Lead-Acid				
	HgO/Zn AgO/Zn	Ni/Cd						
1MW								
1kW								
1W								
1mW								
1μW								

Figure 2: Applications of Batteries in Photovoltaic Systems.

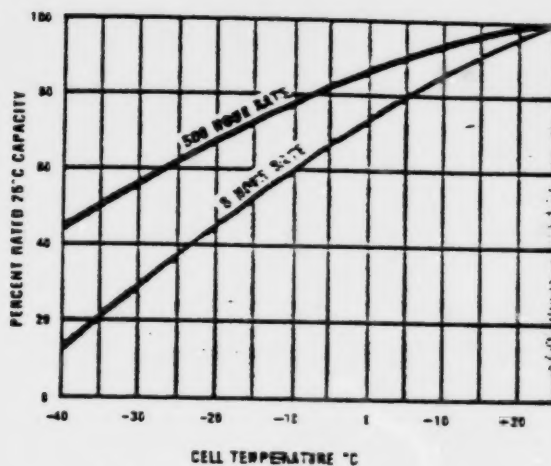


Figure 3: Capacity Versus Temperature Curves for a High Rate (8 Hour) and Low Rate (500 Hour) Discharge of a C&D PV Battery (Courtesy of C&D Batteries) [5].

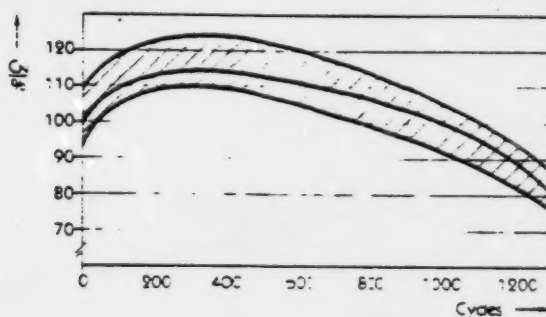


Figure 4: Capacity as a Function of the Cycle Life of a Varta Eloc PV Battery (Courtesy of Varta Battery AG) [7].

SLIDE NUMBER 90

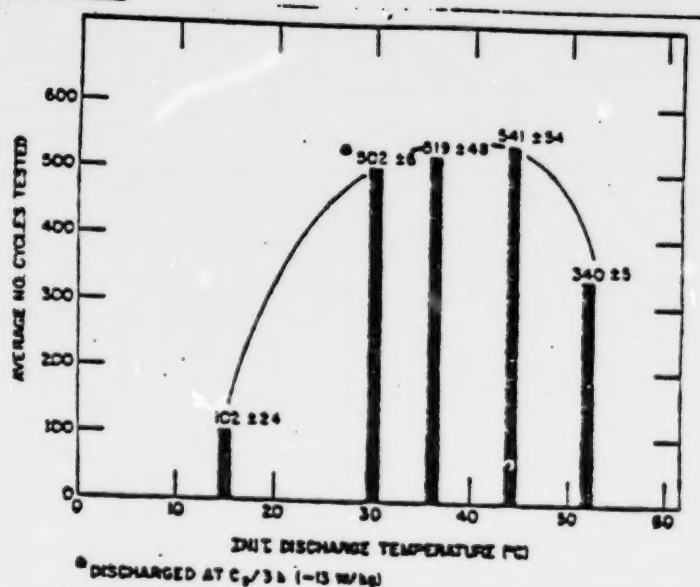


Figure 5: Cycle Life of the Globe Union EV 3000 Battery as a Function of the Temperature (15 W/kg to 80% DOD) [8].
SLIDE NUMBER 92

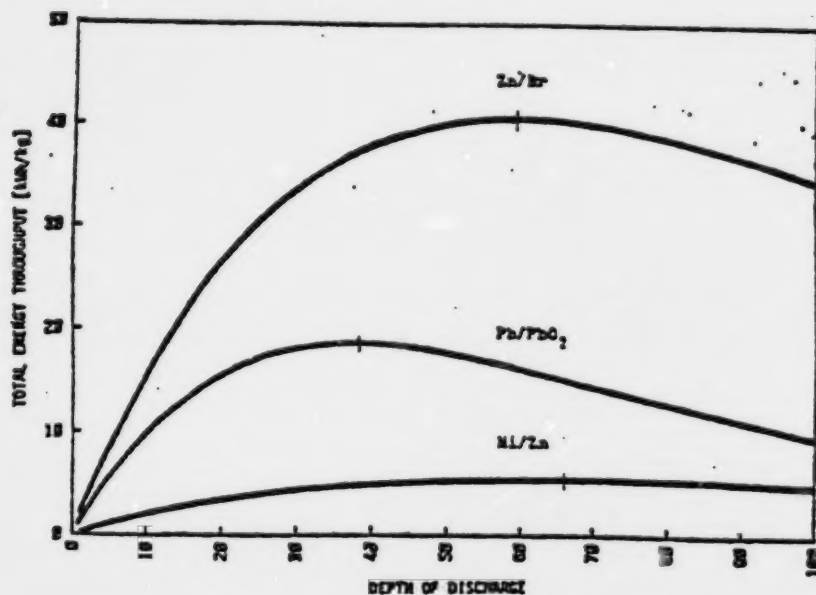


Figure 6: Total Energy Throughput (kWh/kg) as a Function of the Depth of Discharge for Several Batteries [9].
SLIDE NUMBER 91

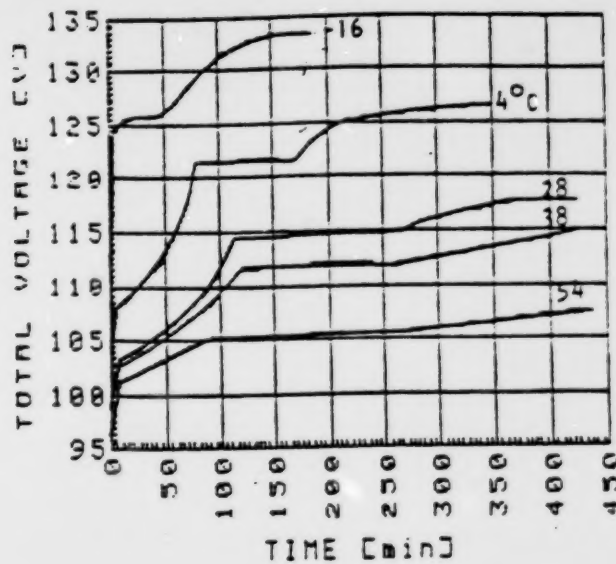


Figure 7: Voltage Response of a 96 V Exide XPV23-3 Lead-Acid Battery at Different Temperatures [11].

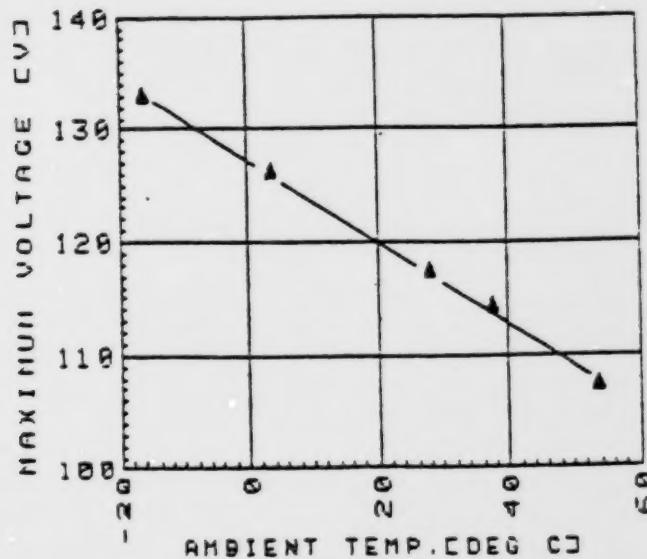


Figure 8: Maximum End of Charge Voltage as a Function of the Electrolyte Temperature for a 48 Cell Exide XPV23-3 Battery [11].

SLIDE NUMBER 93

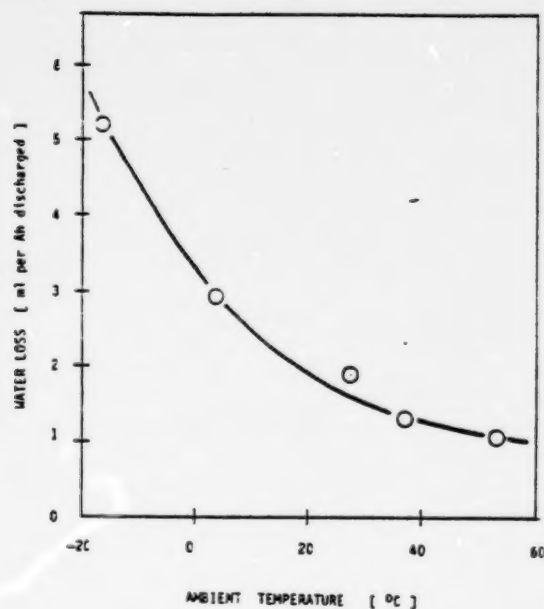


Figure 9: Water Loss of a 96 V Exide XPV23-3 Lead-Acid Battery During Charge as a Function of the Ambient Temperature.

SLIDE NUMBER 94

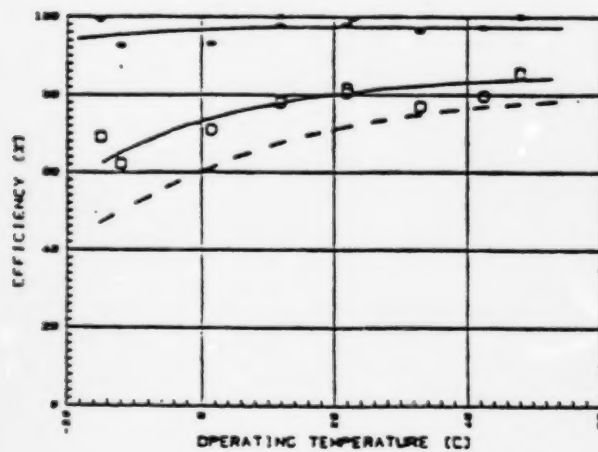
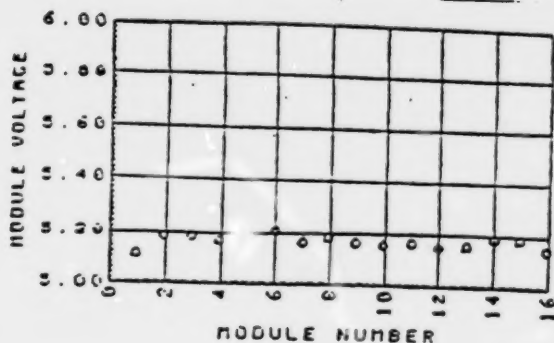
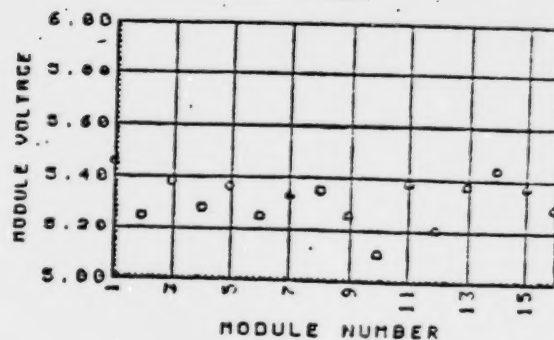


Figure 10: Ah (*) and Energy Efficiency (□) for the ALCO 2200 Retrofit and Energy Efficiency (--) of a ALCO 2200 Battery [12].

SLIDE NUMBER 95



a) Matched Battery



b) Unmatched Battery

Figure 11: Voltage Under Load Profile at the End of Discharge (5.1 V) of a sixteen 6 V Module Lead-Acid Battery [6]. a) Matched Battery b) Unmatched Battery.

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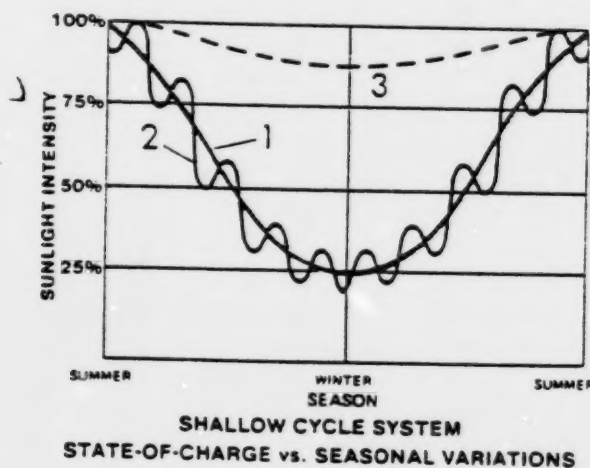


Figure 12: Variation of Sunlight Intensity and Battery State of Charge Over a Period of One Year [5].
 (1) Sunlight Intensity, (2) Battery State Of Charge
 (3) Average Battery State of Charge with Oversized PV-Array.

SLIDE NUMBER 100

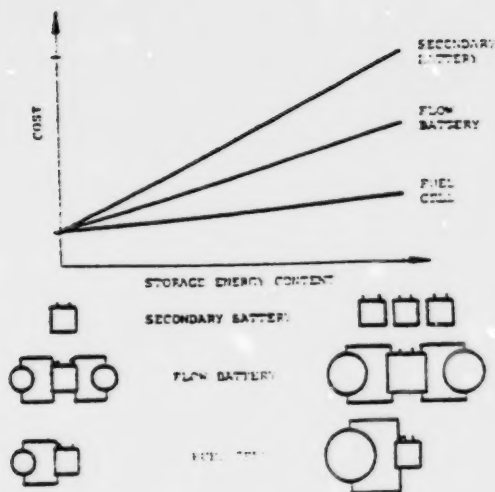


Figure 13: Capacity-Cost Relationship for Energy Storage Systems with Constant Power Requirements [1].
SLIDE NUMBER 102

ZINC-BROMINE CIRCULATING BATTERY

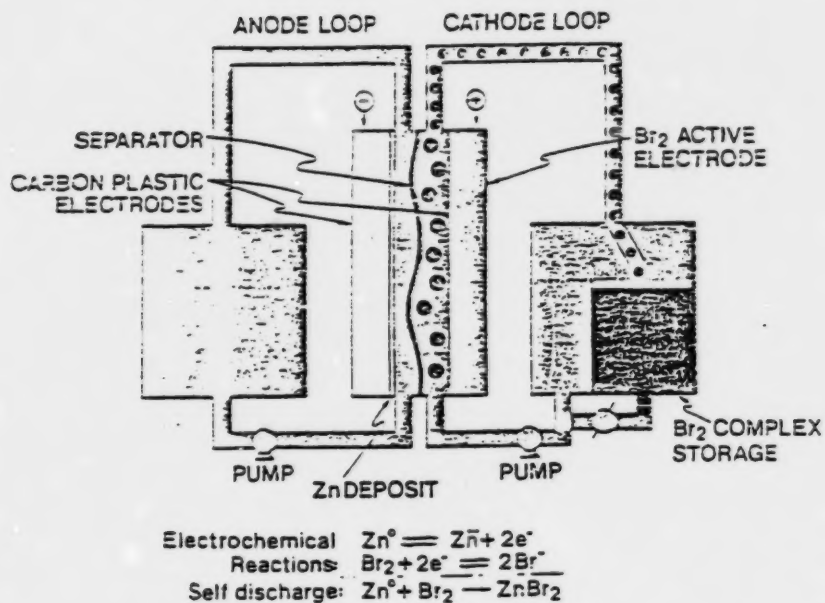


Figure 14: Operation Principle of a Zinc-Bromine Flow Battery [2].
SLIDE NUMBER 103

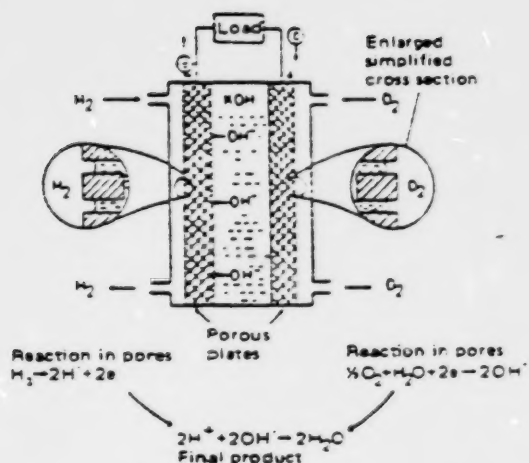


Figure 15: Operation Principle of a Hydrogen-Air Fuel Cell.

SLIDE NUMBER 104

FUNCTIONAL REQUIREMENTS OF STORAGE BATTERIES
IN PHOTOVOLTAIC SYSTEMS

RATED POWER RANGE	DEPTH OF DISCHARGE		CYCLE OF MAINTENANCE	EXPECTED LIFE
	DAILY	ANNUALLY		
MW	1-5%	80% once a year	up to 1 year	about 10 years
	5-20%	sometimes up to 80%	free	<2000 cycles at 30% DOD
kW	25-50%	often up to 80%	a few times per month	about 5 years <1500 deep cycles
W	1-5%	80% once a year	1-3 years	10-20 years incl. 20 deep cycles
	5-20%	sometimes up to 80%	a few times per year	about 5 years <500 deep cycles
μW	1-5%	80% once a year	free	about 10 years incl. 100 cycles at 80% DOD

Table 1: Functional Requirements of Storage Batteries in Photovoltaic Systems.

SLIDE NUMBER 105

CONTROL EQUIPMENT

- MR. WILLIAM B. REVER

(Mr. Rever is Product Manager, Systems, for the Solarex Corp. of Rockville , Maryland, USA, one of the world's largest producers of PV modules and hardware.)

---SLIDE NO. 106

I'd like to start out with an overview of system control and regulation. First of all, the purpose of system control is really to maximize system performance and efficiency. Translated, that means maximizing battery life in a stand-alone application.

There are a number of desirable characteristics for system control and regulation equipment that we'll go into. We'll look at the methods of operation and system interaction and, finally, what the control elements and application techniques are for those control elements and some specific designs of control devices and their characteristics and a few examples.

---SLIDE NO. 107

The first thing we'll look at is what are the really desirable characteristics of control equipment. Probably, the first is high operating efficiency, and there are a number of characteristics to that.

First, you want to have as low as possible a voltage drop between the array and battery. As we'll see later, depending on the choice of the control element, that voltage drop can vary rather dramatically.

Second of all, of course, you want to have a low charge drain on the battery. It's especially important that that be true during low states of battery charge. Obviously, you don't want to make a bad situation even worse by drawing current off of an already low battery.

Finally -- and this is something that's rather unique in photovoltaic applications as compared to other kinds of battery charging -- you want to maximize the current flow from the array into the battery. This is important

because otherwise you won't be getting the maximum useful energy out of the photovoltaic array. It's different from other types of battery where you're really not concerned about the amount of energy used on the front end.

Of course, you have to have high reliability. Most PV systems are in remote, stand-alone kinds of applications, so you have to have a low failure rate under field operating conditions. One thing to look for in the design is, is it fail-safe? What happens if certain parts of the unit fail? Is charging still allowed? Is some fraction of charging still allowed? Does the system go down completely? That's an important consideration.

You also want to have accurate charge control. You want to be able to charge the battery to its design point repeatedly within the recommended tolerances of the manufacturer.

You want to permit full charging. That is, you want to get your battery up to a hundred percent state of charge because otherwise you will severely limit the battery life. On the other hand, you also want to minimize overcharging because of the effect of electrolyte loss and the increased maintenance requirements.

You also, of course, need something that's environmentally protected. You want to make sure that it's capable of withstanding the environment as far as temperature and humidity is concerned against an ocean environment, salt spray, ice build-up, that type of thing, mechanical shock. A lot of times, the transportation to the site is very rough. You want to make sure that it can withstand the rigours of actually getting to the site and being installed.

---SLIDE NO. 108

Now, in the cases where you do have load control elements -- this would be generally for more sophisticated, larger arrays; let's say over fifty watts -- you want to make sure you also have accurate load control capable of preventing excessive battery overcharge, and in certain specific applications, you have other kinds of load control that are required.

One of the most common in the telecommunications

application is an additional load voltage control, which serves the function of making sure that the equipment does not see the full voltage swing of the battery in their charge-and-discharge cycle.

Also in larger systems, typically, you want to have some kind of accurate and useful monitoring instrumentation. Generally, that wouldn't be required for very small systems, but in large systems, it's useful.

One thing that's important, especially in telecommunications or electronics power supply applications, is you want to make sure you have a minimum effect on the quality of power to the load: low levels of interruption; i.e. high reliability; and also, low levels of noise, especially r.f. noise. That, as we'll see later, can also affect the type of regulation that is best for a given application.

Of course, you want something that's easy to use. You want something that's going to be readily installed, easy to operate, and also something that can be easily troubleshot, either in the field or in the local service operation.

Finally, you generally want to select something that's got a proven design to it, where there is actual field experience and it's not just the first of its kind or a one-of-a-kind type unit.

---SLIDE NO. 109

There are a variety of ways of accomplishing the charge control task. I'm going to go through a few of them and various terms and what they mean.

Probably, the most common type of array control is an open-circuiting device, also sometimes called a series regulator. Basically, it does just what its name implies. It imposes a series element in the array path to act as the active control element. That control element can be a number of different items.

The converse to that is the short-circuiting type, also called a shunt regulator. What that does is it imposes a shunt path between the array and battery and controls by taking the PV array down towards the short-circuit side of its operating curve.

Variations on those themes: You can have incremental control, which typically is used in larger systems. What this technique does is it splits the array up into a number of different parallel segments and controls each one independently or in step, thereby giving you a measure of step-type control. Usually, in most cases, it's a two-step type charge-control process.

Usually, the way it works is that, as you get into higher states of charge, you switch out part of the array, leave another portion connected, and then, as you reach an even higher state of charge, you switch out the entire array. Typically, that's used with an open-circuiting type of control.

You can also do a similar technique which is called bypassing. It's a little bit trickier to do, the way it's done, and it's only applicable to higher voltage systems. When you have several modules in series, you can limit the current flow into the battery by switching one module out of the series string and forcing the array to operate on the other side of the peak power point and thereby limiting the current that way.

Now, it's typically only used for fairly large high voltage systems, but it's a rather clever way of accomplishing the charge control. It doesn't require the absolute control of a large amount of power in itself or switching of large amounts of power.

There are some other terms that are used in the regulation area. One is pump charging. Basically, all pump charging refers to is repeatedly driving a battery into the gassing range. Typically, that's used to prevent stratification of the battery cells.

Switching regulation is another term you'll hear. It can be done either in open-circuit or short-circuit configuration. It usually refers to something that's switching on a frequency that's anywhere from a few hertz up to a few kilohertz, although some people are using switching frequencies up to 100 kilohertz. It's similar to pump charging except that the frequency rate is substantially higher.

Older styles of regulation use a tapered charging type of technique, usually a linear series or linear shunt

regulation. The advantage of that is that you have a tightly controlled charge regime for the battery, but the disadvantage, of course, is that you are required to dissipate a fairly large amount of power and that limits the application to fairly small systems of a maximum of a few hundred watts.

Finally, you have what I've called a "one-shot control," and that's a control technique whereby the regulator looks at the battery state of charge, basically, once a day, usually when the array turns on in the morning. If the battery is at a low state of charge, it basically turns the array on. If the battery is at a high state of charge, it basically leaves the array off, so you have one control point per day. It's a very inexpensive type of regulation.

---SLIDE NO. 110

These are some simple circuit diagrams for types of circuits that might be found in regulators. The first is a fail safe circuit using a series design, series regulation control. Basically, what it does is, if the series element fails, it allows for a by-pass circuit using a solid-state relay to by-pass the failed series element.

The other circuit is a similar type of device, only it's used for shunt-type regulation. Again, if the shunt-type regulator element fails, there's another element basically in series with that element that will open up and allow the array to charge the battery even if the element fell short.

---SLIDE NO. 111

These are some very basic regulator circuits that are in use. First is a series type regulator. You can see, basically, that all it is, is there's a transistor in the series current path between the solar array and the battery. There's also a blocking diode, of course, in the circuit to prevent reverse flow and, basically, an electronic control board to turn on the transistor or turn it off, depending on the state of battery voltage.

The second shows a typical shunt regulator. Basically, it operates in virtually the same way with the exception that, as the battery reaches a high state of charge, the

power transistor is turned on to shunt the array current past the battery circuit as opposed to opening up the array circuit.

Finally, there's an example of the switching regulator configuration, in this case a switching shunt regulator, which basically operates in the same mode except at a high-frequency type of operation as opposed to being a linear device.

---SLIDE NO. 112

Now, we've seen a number of different circuits and configurations that can be used for control. The next thing I want to get into is the type of control elements that can be used.

The first category, of course, is electromechanical control elements, and they can basically be either a simple relay, which can be used in either a shunt or a series configuration and can be used for either by-passing or shedding.

The second type of thing is a mercury displacement type of relay, which can also be used in either shunt or series configuration and also for by-passing or shedding. This type of unit can also be used for pump charging because it has a capability for a large number of cycles and can be repeatedly pumped without incurring a penalty in reliability.

Both of those units are typically used much more often in the open-circuit configuration than in the shunt configuration.

The second major category of control element is solid-state units. The simplest, of course, is just a zener diode. These are typically used on very small systems, generally never more than about forty watts. Basically, all it is, is a zener diode put in a shunt configuration with the array. As soon as the battery voltage reaches the zener point, the array is shunted.

It's very simple. However, there are certain problems associated with it. The zener points are not all that accurately controlled. Generally, they also have a temperature coefficient that's the inverse of the battery, which leads to problems in any kind of

temperature extremes. In addition, they also require power dissipation, so they're not suitable for any very large systems.

You can also use a silicon control rectifier. Typically, they are used in a shunt configuration for a very simple regulator using the one-shot control approach.

One of the older types of regulators and one that's been in use for a long time uses just ordinary power transistors, and they can be used in either series or shunt configurations and either in linear tapered charging control modes or in switching modes.

Within about the last five years, the field effect transistor has been used much more extensively in control. Typically, it's used in a series configuration and usually used for array shedding.

---SLIDE NO. 113

Now I'd like to go quickly through some specific designs and characteristics. Probably one of the simplest types is a series relay, a very simple, low-cost design. It generally has a low series voltage drop, minimal power dissipation, of course, because the only power dissipation during operation is the voltage drops in the contacts and whatever is drawn by the coil of the unit.

There is some moderate current required for coil operation, which is a drawback. The unit can have a low reliability unless you minimize the number of contact closures on the unit.

It has a moderate efficiency depending on the cycle rate. Charge control accuracy really depends on the cycle rate. If it's heavily controlled, your charging accuracy is not going to be as good. Basically, this type of unit is recommended in low-reliability applications where cost is really a driving factor.

The next common type of unit is a series transistor control. That's also a simple, moderate-cost design. There's some series voltage drop, of course, across the active element. Fairly minimal power dissipation is required, low current required for transistor operation, relatively high reliability, as there are no mechanical elements involved, moderate to high charging efficiency.

good control accuracy with a tapered charging technique, and a high resistance to environmental stress if it's designed properly. It's generally recommended for general purpose and low to moderate sized power requirements.

---SLIDE NO. 114

Next, we have a shunt silicon control rectifier. That's a very simple, low-cost design. There is no voltage drop as there's no series element, low power dissipation.

The biggest problem with this device is the poor charge control accuracy because it only looks at the battery state of charge once per day, so if there is a load that comes on in the afternoon that pulls the system down and the regulator has already determined that the battery was full, the unit won't come back on that day.

The next type is a series mercury displacement type unit, also a simple, moderate-cost design, high charging efficiency, high reliability. It's generally recommended for fairly large power, high-reliability applications.

---SLIDE NO. 115

There is also a switching shunt regulator, which is a relatively new design. It basically has the advantage of very low power dissipation and high efficiency and the ability to control a fairly large amount of power for its size.

The series f.e.t. is also a fairly new design. It incorporates fairly moderate cost, fairly high efficiency except for some series voltage drop, and is also recommended for general medium system size applications.

---SLIDE NO. 116

Shunt regulators are generally very high-reliability units. They do require power dissipation, which limits their application to very high-reliability applications of less than about a couple of hundred watts.

Finally, we have very simple shunt zener diodes, which are used only on very small systems where accurate charge control is really not a necessity.

---SLIDE NO. 117

Now I have a couple of examples of units that Eric showed earlier. This unit is a small switching shunt regulator that can either be installed directly on the module, which is typical application, or it can be installed in a separate battery box near the battery.

---SLIDE NO. 118

This is a larger series transistor type unit used for systems of up to about two hundred fifty watts, and that's it.

PERFORMANCE MONITORING

- MR. PER DREWES

(Mr. Drewes is Design Specialist, Alternative Energy Systems with Ontario Hydro, Toronto, Ontario, one of Canada's largest utilities)

I've got twenty minutes to sum up five to six years of work, so I'll try to mumble as quickly as I can. What I'm going to do is use the slide projector to show some of the equipment I've installed in the field, the PV equipment and the monitoring equipment, and then for the second half, I'll use the overhead to show some of the results of that monitoring program that we've got for the equipment in the field.

I'm going to ask you to remember the first half as I go into the second half. Remember, I'm counting on you, and I may just stop and ask you questions, so pay attention.

---SLIDE NO. 119

That's the first installation. That's the Atikokan installation. That's 2.4 kilowatts. It powers a remote air pollution monitor. It went into service in 1981. That's a stand-alone system. It's got four tons of batteries in there to keep it running during that sunless period.

---SLIDE NO. 120

The second installation is a 1-kilowatt grid-connected system at Kortright, just north of Toronto here. That went into service in 1984.

---SLIDE NO. 121

The third system is a 10-kilowatt system that just went in this past summer in a community called Big Trout Lake. That's a diesel hybrid system.

Going back to the first installation, we were pretty naive in 1981. There are two types of tests that we do. There's the short-term, just the acceptance tests, if you want, and then there's the long-term monitoring.

In 1981, the only acceptance test we had was we measured the voltage across the four modules before we connected and then we measured the current through the four modules after it was connected. It's a 48-volt system, so there are strings of four modules, a hundred and some modules altogether.

It's a simple test, but we did find out that one array didn't work after it was exposed to sunlight. It turned out all the shunt diodes were way underrated and they burned out the first day of operation, so we spent a day replacing all those.

For long-term monitoring, as I said, the power is used to run an air pollution monitor. We're measuring sulfur dioxide up in the bush in northern Ontario, and we're only using one channel on the data logger, so we rode piggyback and used the seven other channels for the solar data.

---SLIDE NO. 122

That's the installation there. The top machine is the sulfur dioxide monitor, the second unit is the calibrator, and all the black stuff down below is the actual data logger transmitter. That is on site fourteen kilometres into the bush.

We installed a pyranometer to measure sunlight. We also measure ambient temperature, battery voltage, the current from each of the three arrays. There were three arrays put in service, one from each of three different Canadian manufacturers.

An interesting aspect of this instrumentation is that it has to operate at minus 48 degrees ambient temperatures. The sulfur dioxide monitor, in particular, has to run between 70 and 75 degrees Fahrenheit.

In those cold conditions, of course, PV doesn't provide much in the way of power for heating, so we just used the waste power of the instruments themselves. They consumed two hundred watts continuously, and as any physicist here knows, all energy ends up as heat, so by just enclosing the instruments, they heat themselves. The problem now becomes one of cooling in the summer, and we have a big copper loop in through the ground to cool it in the

summertime.

The data from the installation was transmitted from the installation itself, picked up at a central receiver, and then stored on mag tape at the central receiver. This also picks up the air quality from eight other stations in the area. We then sent this tape down here to be processed.

One of the problems with this project is that so many people handle it. The air pollution people took the tape. It was processed by Hydro's billing people. Research Division wrote the hard copy, and it took me about three or four months to get that.

For our next installation at Kortright, which was in 1984, this is a grid-connected system. It feeds the curator's house, and if he doesn't need the power, it goes into the utility.

---SLIDE NO. 123

Here's the actual 1-kilowatt system. There's a long story about the purchase of modules on this project. Don can fill you in later, but needless to say, the second supplier of PV modules met all our criteria.

We tested each one of the modules first at the solar simulator in Ottawa and then we brought them to the field. That's a TPK system, and two years later, it's still running as well as it did when it was first installed.

We were pretty naive when we put in Atikokan. That is to say, we could only tell voltage and current. We only knew if the modules were running or not running. Now, for this system we have a tracker, so we know we have to characterize the modules.

Not to be outdone by anybody, Ontario Hydro developed a sophisticated variable load. This particular unit is made by Mitchell, but Allen's apple juice makes just as good a model as this one here, and they're available locally.

What you do is you connect one end of your PV grid on here after you take the top off. Then you take all of the plastic coating off on the side here. You fill it

with water, which is usually locally available. You sprinkle a little bit of salt in. Stir it; don't shake it.

Then you get your poor assistant here to grab the other end of the array, you clean off a bit of wire, and you submerge this here while you've got your Radio Shack voltmeter across and your Radio Shack ammeter in series. You take the readings as he holds this steadily in here. The further down, more wire into the water, you get a lower resistance. You can select any power point you want on the modules.

I used this for the 1-kilowatt. I've also, in fact, used it in Atikokan, but I shied away from it at ten kilowatts. We haven't used it at Pickering, either.

---SLIDE NO. 124

Going on, we also did some more sophisticated tests. We were checking for radio interference. Needless to say, there's no interference unless you've got your ghetto-blasters standing about two feet in front of the modules, but that's no big problem.

We installed an inverter supplied by U of T, and we also installed a data logger which we borrowed from NRC. I should, at this time, say that these projects are all co-sponsored. Hydro is involved. National Research Council is involved. EM&R is involved. Ontario Ministry of Energy, Canadian Electrical Association, Kortright Conservation -- we'll take money from anybody, really.

---SLIDE NO. 125

We also did some other testing, since we had the data logger there. Here, we mounted those two modules, one with a reflector and one without. They're mounted separately and they run an attic fan to keep the main array cool, but we also monitored them to see the effect of the reflector, what advantage there is to putting the reflector in.

---SLIDE NO. 126

The Kortright 1-kilowatt installation: Last year, we added three more kilowatts to it in preparation to going up to Big Trout Lake. We were testing things like

support structures and that sort of thing.

There, we've expanded Kortright from the original one kilowatt, three more individual kilowatts added. There's the two modules, one with reflector, one without. Kortright also have a solar tracker which we tested for its performance. That was all in preparation for going up to Big Trout Lake.

---SLIDE NO. 127

Big Trout Lake here, about four hundred to six hundred kilometres north of Thunder Bay, a remote Indian community, about seven hundred people. PV-diesel supplies the power to the community on a mini-grid.

One of the reasons for going, aside from the high fuel costs up there, is that Big Trout Lake is a major weather station, so we've had twenty years of detailed solar radiation data available to us.

---SLIDE NO. 128

That's downtown Big Trout Lake and there's the weather station. We installed three hundred modules up there. Again, each one of the modules was tested in a solar simulator before it was packaged and sent up. I also tested for ground leaks at the factory.

Once they were installed in the array, as I say, I didn't use my load, but I did measure for ground leaks again by just connecting the high and the low input to ground and measuring the differences in voltages.

---SLIDE NO. 129

There's our diesel generator. It runs day and night. We've got three different sized diesels. The PV system just rides piggyback on it. When it's sunny, the throttle cuts back and we're saving fuel.

---SLIDE NO. 130

This is the inverter that went on. It weighs five hundred pounds and there was about two hours of discussion about how to get it off the airplane before we carried it in, but the next day it went into operation.

---SLIDE NO. 131

There's the data logger we got from NRC, and we're picking up about six channels of solar information and about six channels of diesel community power consumption information on that unit.

---SLIDE NO. 132

On top of the diesel building, we've got a solarimeter there to measure the sunshine so we can correlate output of the PV array of the sunshine. The middle module there is our power tracker. It's three cells cut in quarters. That makes twelve, so we're getting a 6-volt signal on that. We multiply that by about one hundred to establish the operating voltage of the array itself. That's how we power track.

---SLIDE NO. 133

There's the array itself. Not only is our data logger looking at what the solar installation is doing, but we are also keeping a close eye on what is happening on the demand side in the community.

---SLIDE NO. 134

Now I'll try to use the overhead and show you some of the results. As I said, we're operating an air pollution monitoring network up in Atikokan. The solar station is one of about six or seven. Our particular channels that are radioed into the central receiver are channels six and seven.

Here's the first data, and it's coming at 9:00, 10:00, 11:00, and 12:00. There's not too much sulfur dioxide: in parts per billion, 239. At 11:00 you can see that it's gone away. I guess the wind shifted.

This is our information here. The solar radiation is 177 watts per square metre. As you can see, it's up by noon here to about 578. The value voltage is sitting over here. It's supposed to be a 48-volt system.

That particular time, April 1985, the system was not a 48-volt system because three of the twenty-four cells had frozen solid, cracked, and were out of service, so we

were really running at about a 42 to 43 volt system. It ran okay. It just had to draw a little more current than it's supposed to.

You can see, as the sun comes up and the PV system starts charging, the voltage goes up. This is our load. It's supposed to be about two hundred twenty watts, but you can see it's a little higher than that.

These are the three solar arrays: one, two three, and the totals. You can see, at noon hour, one array is producing two hundred eighty-seven watts; another one, three twenty-three; another one, two hundred fifty-one. They were all rated at eight hundred watts. The PV cell efficiencies, you see here, and there's the total output for the array.

We've had some trouble with this one and that one. The Silonex array in the middle, eight hundred watts, is producing now, five years later, as well as it did when it was first installed. This spring we put in another 800-array to make up for the losses of the other two.

---SLIDE NO. 135

Now, we processed this data and we can get out all sorts of things. Here's some data, April 1st, 1982. We usually pick the first day of the month. You can see the sunshine. As the day wears on, the sunshine comes up and goes down again.

Here are the three outputs of the array. We've picked the average day as the first day of the month and done monthly summaries.

---SLIDE NO. 136

You can play around with that data any way you want. With this one for the battery storage system, we're actually interested in the ingoing-outgoing energy. This sums up what's happening.

Here's April 1982. We had a very good, sunny day on the first of April. The second two days were pretty bleak. We were using more power than we put in. Here, we had a good period. Here, we had another bad day. Here, we had a good period. Here, the radio went out. Here, we had a good day again. Here, the radio went out. Here, we had

a few days more and then the radio went out, so that's a sum of the net energy. April '82 was a pretty good year, if you remember; I don't know.

---SLIDE NO. 137

I think ours has been in longer than most systems, so I think we've got longer data than anybody else. I took the Silonex array, which is eight hundred watts, still producing, still right on -- can't complain about it. I thought it would be interesting to see what it's done over the years.

One of the main problems is that we have system outages for a long time, not usually for the PV system but due to the radio transmitter and other things external to PV, but I do have a fairly good record.

Here, April 1982, it's interesting to see the capacity factor of the 800-watt array: twenty-five percent in April. You have a little break here, but you see it gets pretty dismal: eight and three percent in December. It climbs back up in January. What you can see here is that the spring is really the best season for collecting sunshine up there.

The capacity factor is what we use at the station. If I say it's twenty-five percent capacity factor, that means that, on the average, this 800-watt system was producing two hundred watts day and night. Obviously, right away, you can't have more than fifty percent because night is cropping up -- day, night; day, night -- so you're down fifty percent, so twenty-five percent is a very good capacity factor, and as you can see, it happens in the spring.

November and December are very dismal days and that's when you need that storage you've got. That's the big problem in the stand-alone systems: how to get through the low-sunshine periods.

---SLIDE NO. 138

Now, as I say, I went back up to Atikokan and characterized the three arrays with my variable load. This is where you get the curve, by moving, as I say, one lead in and out of the solution. I don't want to go into too much detail, but one of the problems

illustrated at Atikokan is that you choose three different manufacturers and their peak power points here, and here, and here occur at different voltages and they're all tied into the same common battery, so you're really putting some of the arrays at a disadvantage.

You should use the same system, but as I say, this was an experiment and it was co-funded and NRC were testing out three different systems, but you should really have it at the same voltage.

---SLIDE NO. 139

Going back down to Kortright with my Mitchell can here, we characterized each of the two strings on the 1-kilowatt TPK array. The reason for that is we wanted to find out where the maximum power point is. The maximum power point is the biggest rectangle you can get under this curve.

There are two strings of fifteen modules. For one, the maximum power point occurs at -- I don't have the numbers written in -- but at two hundred fifty to two hundred forty volts, so that's where we've got to set our inverter to operate at to get maximum power extracted from the PV modules.

You can see the fill factor there is 6.8, and the other one you can't read, but it's .7, which is pretty good for these arrays.

---SLIDE NO. 140

Now, we put on the data logger, and one of the dangers of this is we've got so much information, you don't know what to use, but here's a poor day. There's the insolation in watts per square metre: nothing at midnight -- not surprising. Then it goes up to three hundred thirty-three watts -- not too great. The next day it goes up to 1,033, and so we're looking across there.

That was when we had four kilowatts and we were producing almost 3.7 kilowatts DC, 3.3 AC. The difference is the losses in the inverter. The guy's consuming two kilowatts, so he's exporting 1.2 kilowatts to Ontario Hydro.

There are other parameters over here but Don says I don't have time for that. I can tell you what the temperature was. I can tell you what time of night he got up one day.

---SLIDE NO. 141

We're setting up this on a monthly basis. Here's January of this year. Only on the first day of January has the solar contribution exceeded the demand. At other times, we have to rely on good old Ontario Hydro. The reason it exceeded it was that we went away that day.

---SLIDE NO. 142

We can break it down even finer. Here's the net flow of energy on an hour through the month of March. Anything down here is something that he exported and we bought at Ontario Hydro. I think you'll find in the area under the curve up here, he purchased more than he sold, but there are times when he's exporting three kilowatts and the meter's running backwards and he's counting up his pennies.

We can do all sorts of correlations with this system. It's on a modem in our PC computer. We can deal with it right in our office.

---SLIDE NO. 143

We can do correlations of DC power coming out versus the insolation. The problem with collecting data is that you've got to understand it and know what you're doing. Some of these things, you think that there may be problems in the array because it's not getting the power out that it should be under certain radiation conditions, but the problem really lies in the inverter use because it's not at the maximum power point.

---SLIDE NO. 144

Just to show you that we do get meaningful data, here's temperature rise versus insolation. On a bright day, I think the standards down here show you that you get about a 20-degree rise for solar intensity you get on a standard day, and you get the same curve up here, so we agree with other people.

---SLIDE NO. 145

Here are the inverter efficiencies. This one in particular is the Sunsine inverter for 4-kilowatt units. You can see it climbs up to good efficiency at a very low load. At about one kilowatt, quarter-load, it's almost up to full efficiency.

---SLIDE NO. 146

We can play around with any sorts of numbers we want using this Lotus format on an IBM PC. Here are two days: not a good day; a better day.

This is the effect of adding the reflectors. These are the two modules, the current out of the two modules. The top module is the one that's got the reflector; this is the one that doesn't. You can see that, on a diffuse solar day, it doesn't make too much difference, and even on a good day, the benefits of a reflector on a module aren't that great if it's not tracking the sun.

---SLIDE NO. 147

Up to Big Trout Lake: We've got data coming out our ears. You can get it in any format you want. We've got solar radiation, voltage, array power. Here, we've got the diesels. We've got three different diesels. We can tell at which time of day it turned on and off.

Here's current going into the three phases. Diesel people are interested in this. There's a problem up there in the distribution systems. There's one phase, two phases, and three phases, and it's very unbalanced, which causes problems for diesel generators.

Community demand is right there. They're demanding ninety-six kilowatts at 1:00 in the morning. They start getting up -- what time do they get up? They get up at 6:00 in the morning, some of them. Demand climbs up until it peaks at around a hundred fifty, hundred fifty-five that one day. Of course, they all go to bed again, and then the demand drops down.

The demand starts climbing up again. Here, you get the peak at 8:00 p.m. the next day. Money to doughnuts that's their wrestling on T.V. They all went home and turned their T.V.'s on. There's a lot of wrestling up

there.

---SLIDE NO. 148

Here's some more graphs. If you want graphs, we can sell you graphs by the millions. Inverter output versus solar radiation: We peaked at eight kilowatts on the 10-kilowatt array. The problem is, as I say, you've got to interpret the data correctly. The problem is not the PV array but that you are not tracking right on maximum tolerance, so the inverter has to be adjusted.

We've got some ripples on the DC coming in, so that we're not always on the maximum power point of the array, so even though it's a 10-kilowatt array, we're only extracting eight out of it. As I say, don't blame the array; blame the inverter. We'll get that corrected by putting in some inductors on the DC side.

You can see how radiation varies from day to day: a real rotten day and a pretty good day. This one was so rotten that we even ended up consuming power from the system. Because of stand-by losses in the inverter, we went below.

---SLIDE NO. 149

Here's distribution of loads in the community. Most of the loads occur either at the hundred kilowatts or a hundred eighty. This is of interest to Ontario Hydro, knowing when the diesel can operate.

---SLIDE NO. 150

This is a profile of the load by the community and the PV contribution. Here is the PV contribution, the difference between the two. When we were up at a hundred fifty kilowatts with the solar ten kilowatts, it doesn't do too much, especially at night.

---SLIDE NO. 151

Here's another one: inverter power versus the insolation. I guess I'll come back to the point that the inverter has to be rectified a little bit to pick up as much power from the PV system as it can.

That's what's going on. We've got more monitoring data than we know what to do with. I think we've all done theoretical studies where you spend five or six years modelling things and wondering what's going on. I think this next year is going to be exciting because we've got the hard data on the costs of the system. Now we'll have the year's data on what the PV system actually does, never mind the textbook theory. We'll actually get the numbers. That's it.

TELEM NAK STN: 5
 TELEM NAK STN: 3
 TELEM NAK STN: 4
 TELEM NAK STN: 5
 TELEM NAK STN: 3
 TELEM NAK STN: 4
 TELEM NAK STN: 5
 TELEM NAK STN: 3
 TELEM NAK STN: 4
 TELEM NAK STN: 5

REPORT OF 85/04/14 12:00 104

STN: 1 NYM LAKE
 AVERAGES

TIME	SO2 ppb	NO2 ppb	NOX ppb	O3 ppb
09:00	0	0.0	0.0	0
10:00	1	0.0	0.0	0
11:00	1	0.0	0.0	0
12:00	1	0.0	0.0	0

STN: 2 SWITCHYARD, ATIKOKAN G.S.
 AVERAGES

TIME	SO2 ppb
09:00	
10:00	
11:00	0
12:00	0

STN: 6 FINLAYSON LAKE
 AVERAGES

TIME	SO2 ppb	GT W/sqm	VB V	PLR W
09:00	239	177	43.63	247
10:00	123	261	44.13	293
11:00	0	342	44.75	313
12:00	10	578	46.50	253

STN: 7 FINLAYSON LAKE SOLAR PWR SYSTEM
 AVERAGES

TIME	PS1 EFF1 W %	PS2 EFF2 W %	PS3 EFF3 W %	PST EFFT W %	IEC	IB	IR
09:00	53 3.2	60 4.6	35 2.3	149 3.3	1.1	-1.1	-33
10:00	112 4.5	110 5.9	69 3.9	311 4.7	1.1	1.4	-37
11:00	171 5.4	163 6.5	142 4.7	474 5.5	1.1	4.4	-33
12:00	287 5.4	323 7.7	251 4.9	861 5.9	1.1	13.9	-20

REPORT OF 85/04/14 16:00 104

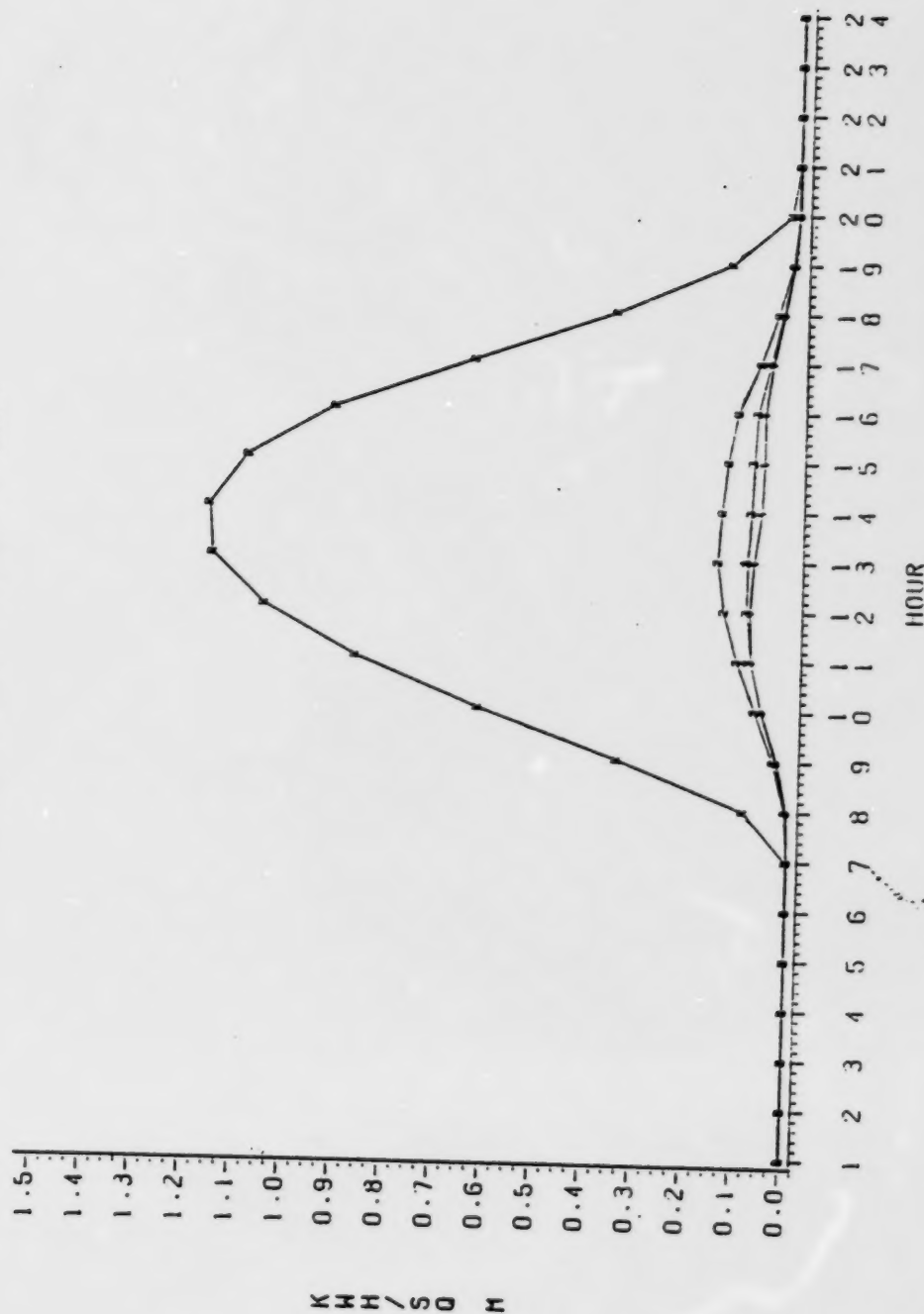
STN: 1 NYM LAKE
 AVERAGES

TIME	SO2 ppb	NO2 ppb	NOX ppb	O3 ppb
13:00	0	0.0	0.0	0
14:00	0	0.0	0.0	0
15:00	0	0.0	0.0	0
16:00	0	0.0	0.0	0

SLIDE NUMBER 134

STN: 2 SWITCHYARD, ATIKOKAN G.S.
 AVERAGES

PHOTOVOLTAIC STUDY - APR 82 HOURLY AVERAGES OF SUB-ARRAY OUTPUTS (UNT-PSI) AND INCIDENT SOLAR RADIATION PER UNIT AREA (GT) SPECIFIC DAY - FIRST OF MONTH



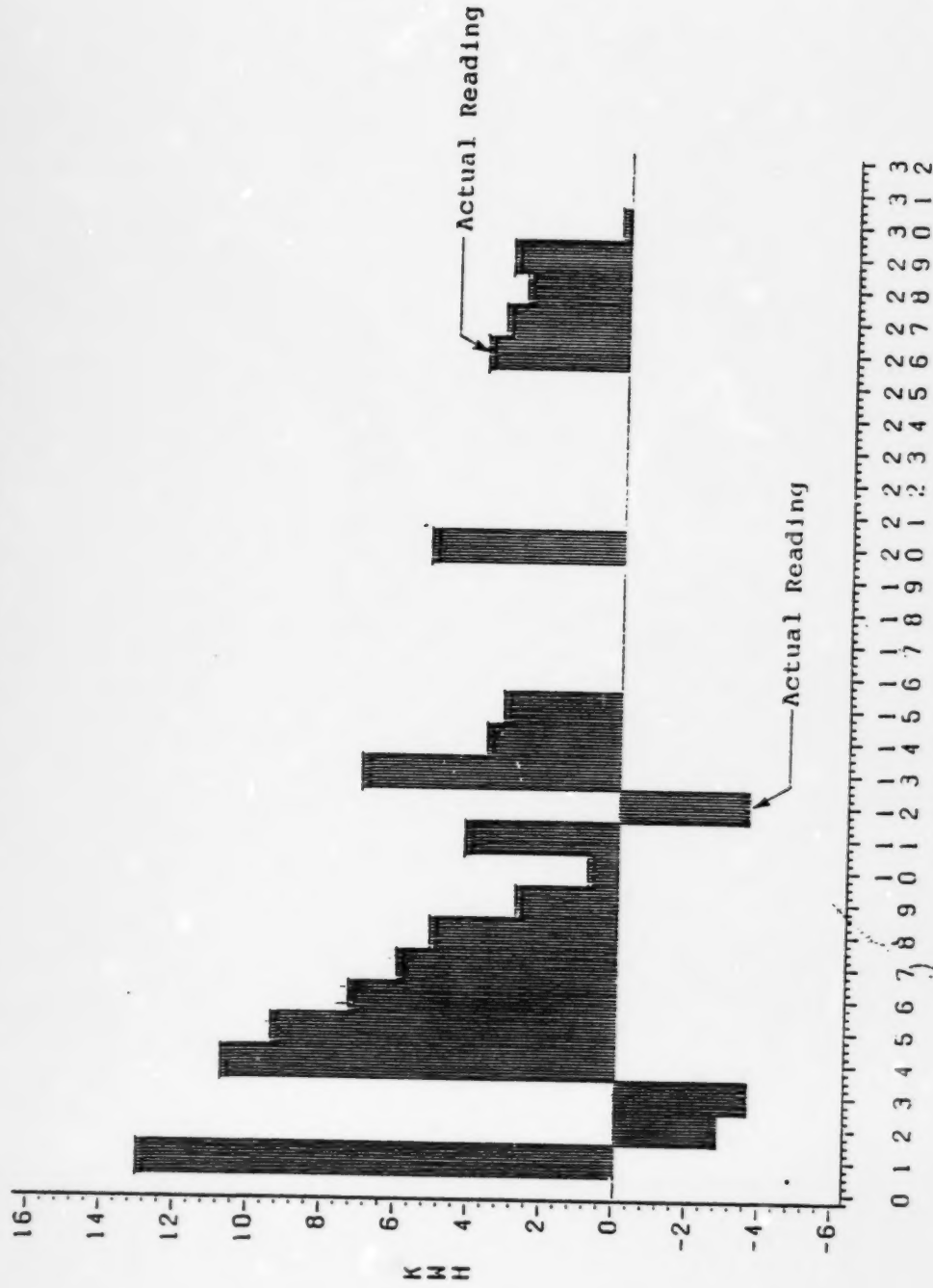
R = INCIDENT SOLAR RADIATION(UNT-RAD)
1.2.3 = SUB-ARRAYS 1.2.3 (UNT-PSI)

SLIDE NUMBER 135

- 141 -

PHOTOVOLTAIC STUDY - APR 82

DAILY DIFFERENCES(DIFF) BETWEEN TOTAL ARRAY
NET ENERGY OUTPUT(TOT-PST) AND LOAD(TOT-PLR)



DAY OF THE MONTH

SLIDE NUMBER 136

NO BAR INDICATES DAY HAS MISSING DATA

- 142 -

TABLE 2

Monthly Performance For 800 Watt Silonex Array

<u>Month</u>	<u>Data Capture¹ (Percent)</u>	<u>Sunshine² Availability (Percent)</u>	<u>Average³ Electric Power (Silonex Array) Watts</u>	<u>Capacity⁴ Factor (Percent)</u>
April 1982	78	24	203	25
May	73	21	162	20
June	88	20	147	18
July	83	20	133	17
August	44	16	89	11
September	74	17	114	14
October	47	10	Power supply shutdown	
November	29	11		
December	25	4	60	8
January 1983	25	14	26	3
February	64	8	93	12
March	94	17	47	6
April	74	21	116	15
May	98	22	144	18
			149	19

↓ System outage inverter damaged.

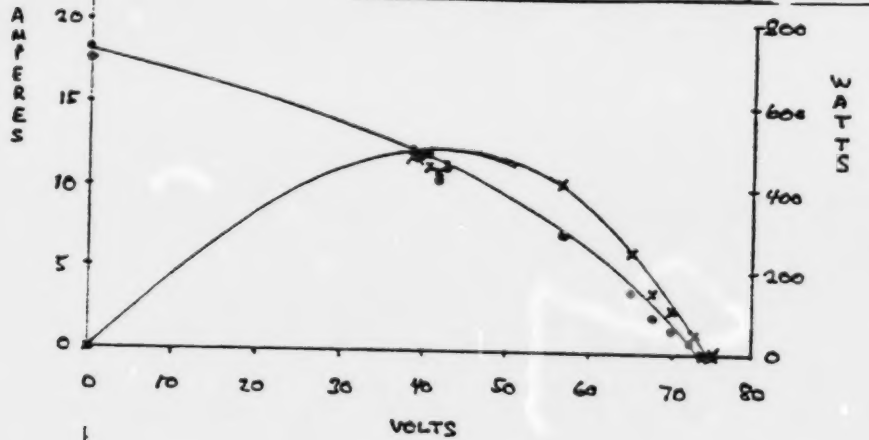
January 1984	13	8	41	5
February	33	17	105	13
March	94	27	169	21
April	94	25	164	20
May	85	19	126	16
June	45	16	102	13
July	93	20	127	16

- 1 Based on number of hourly printouts over the month.
- 2 Calculated from measured kilowatt-hours per square metre (1 kilowatt per square metre times hours of data collection).
- 3 Average power from 800 watt array over period of data collection
- 4 Calculated from measured kilowatt-hours/(0.8 kilowatts x hours of data collection).

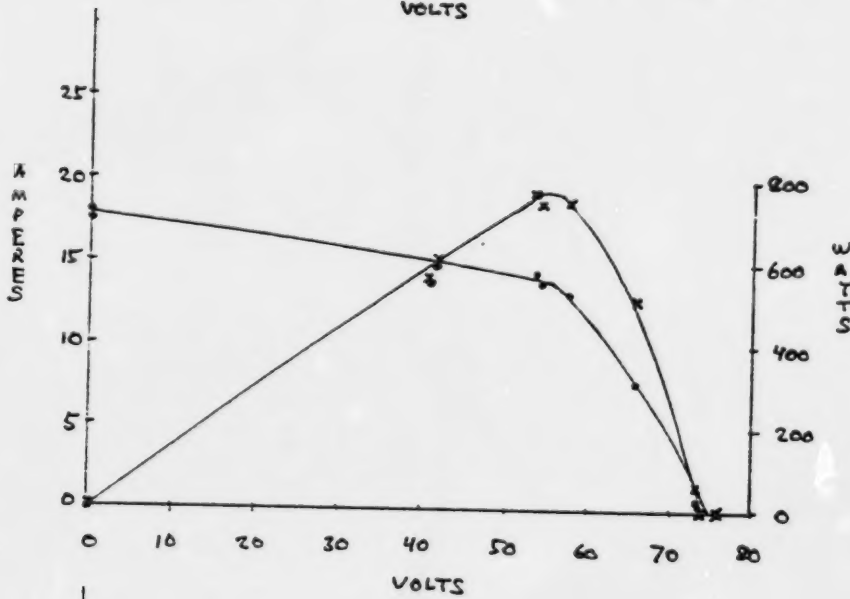
SLIDE NUMBER 137

FIGURE 1

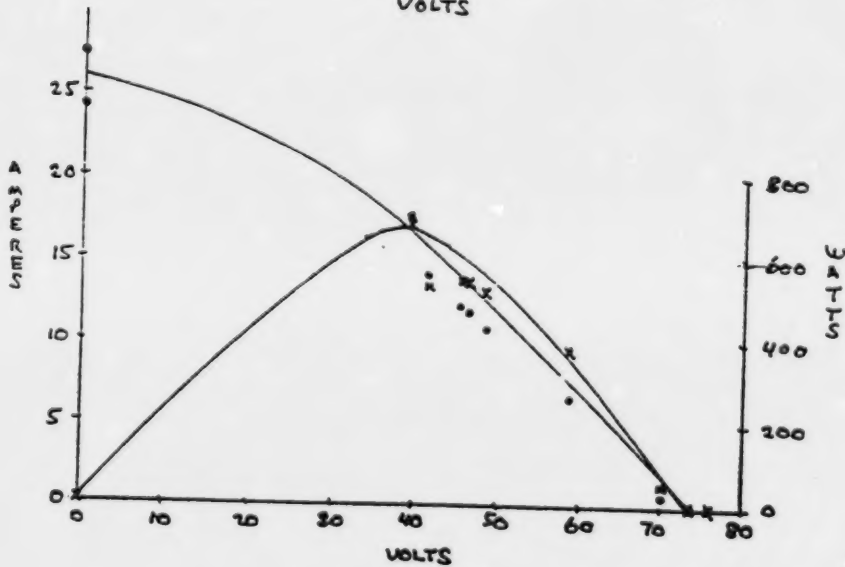
Current (Power) Versus Voltage



TPK Array
Max Power 487 w
PF 0.36



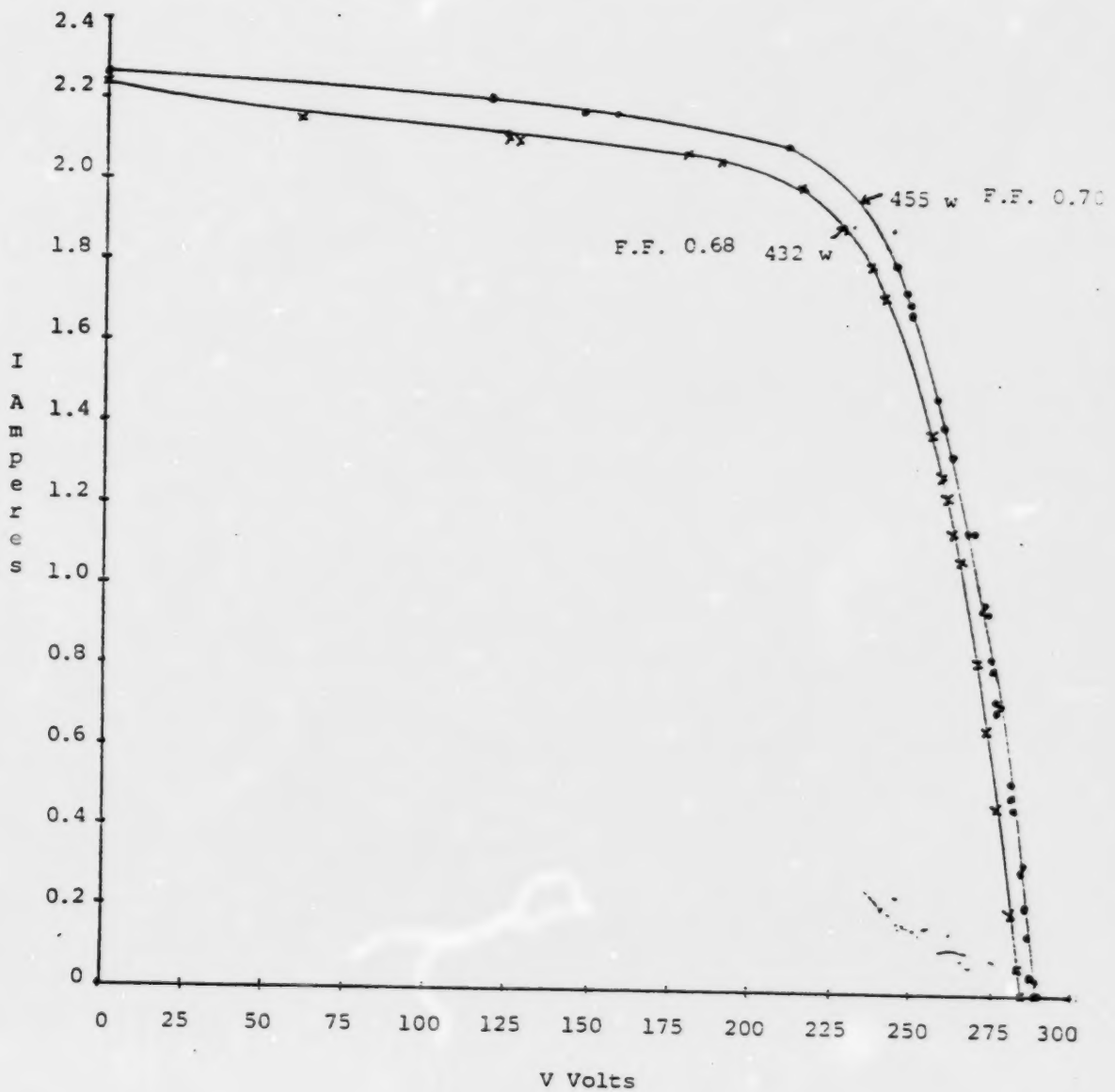
Silonex Array
Max Power 772 w
PF 0.59



Solar Cells Array
Max Power 692 w
PF 0.36

SLIDE NUMBER 138

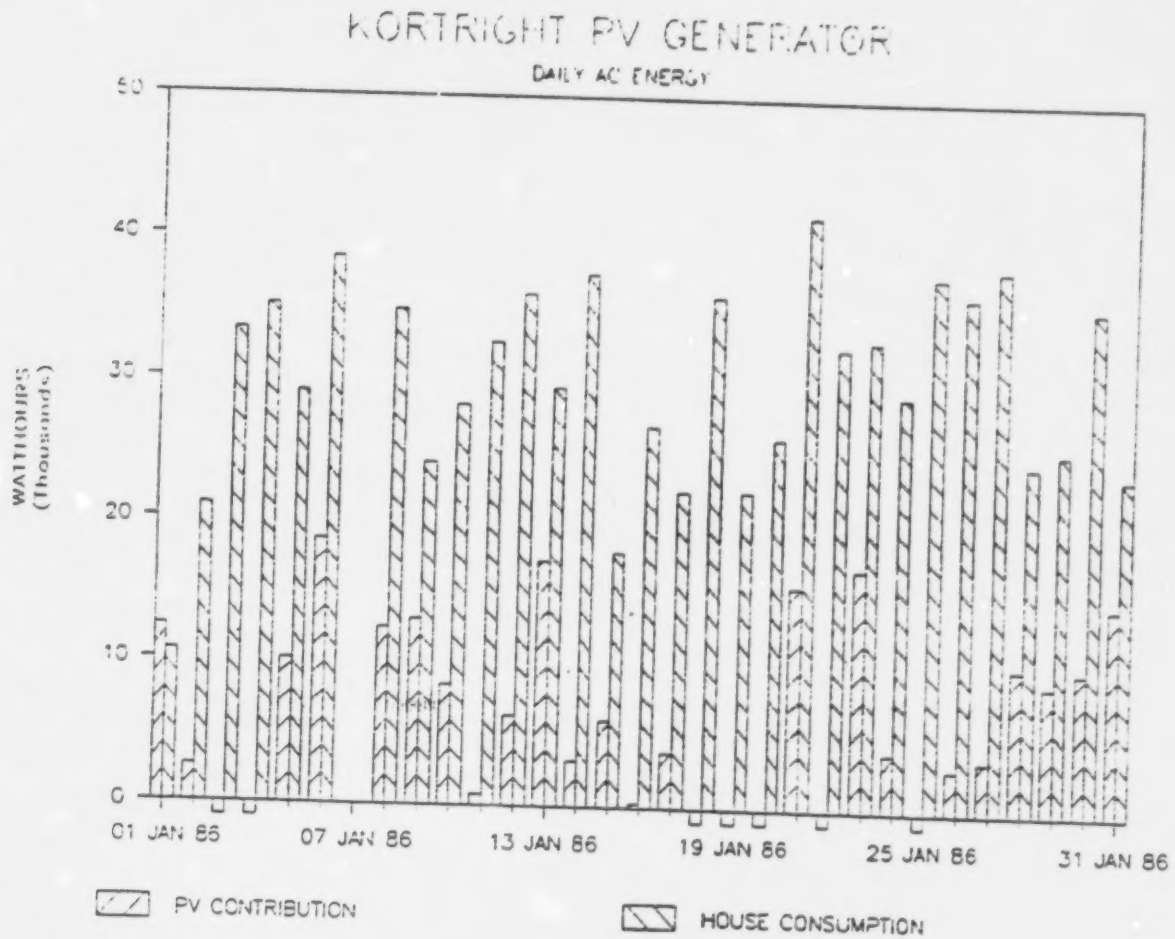
KORTRIGHT PV ARRAY PERFORMANCE CHARACTERISTICS



NOTE: Output corrected to Standard Operating Conditions (SOC)
 Irradiance Level 1000 Wm^{-2} current corrected using linear extrapolation
 Ambient Temperature 20°C voltage corrected using $\frac{dV}{dt} = -2.25 \text{ mV}/^{\circ}\text{C}/\text{cell}$

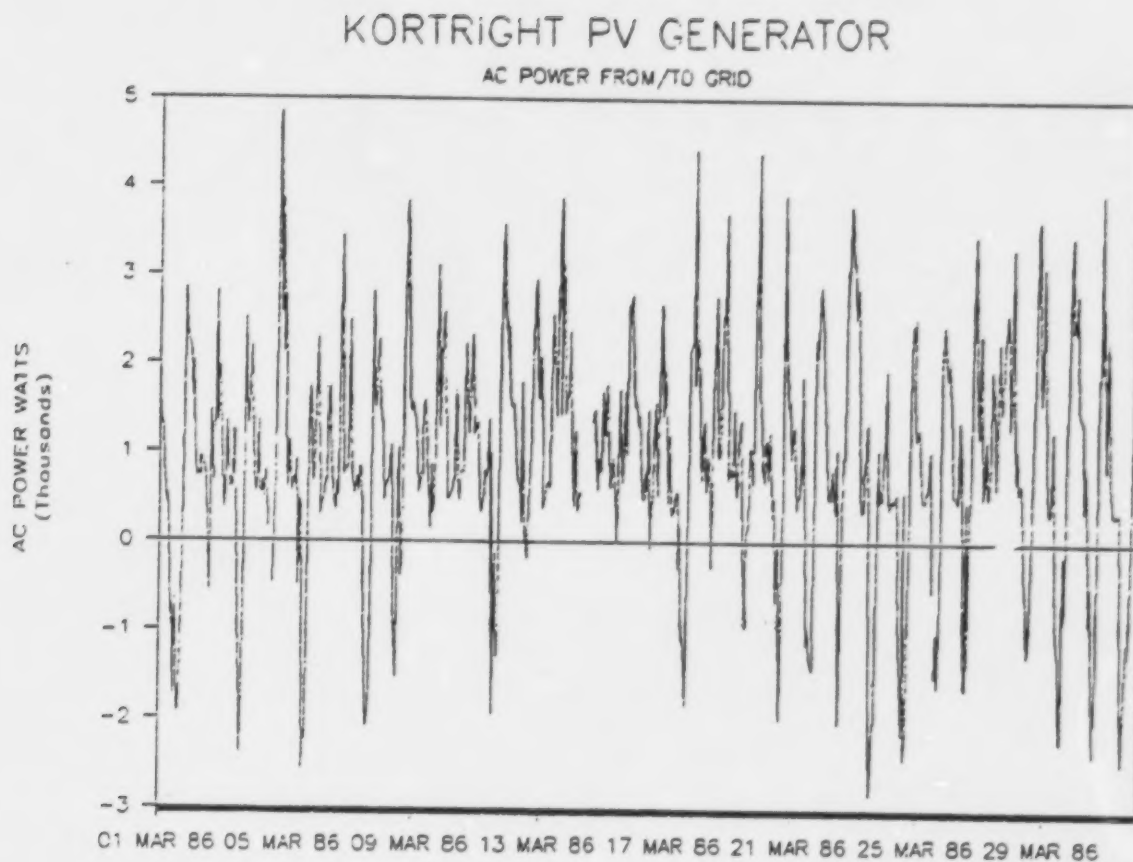
SLIDE NUMBER 139

Figure C2



ONLY ON THE FIRST DAY OF THE MONTH DOES
ENERGY SUPPLY EXCEED ENERGY DEMAND. SOME
GREY DAYS SHOW A NET LOSS FROM THE PV SYSTEM
SLIDE NUMBER 141

Figure C9



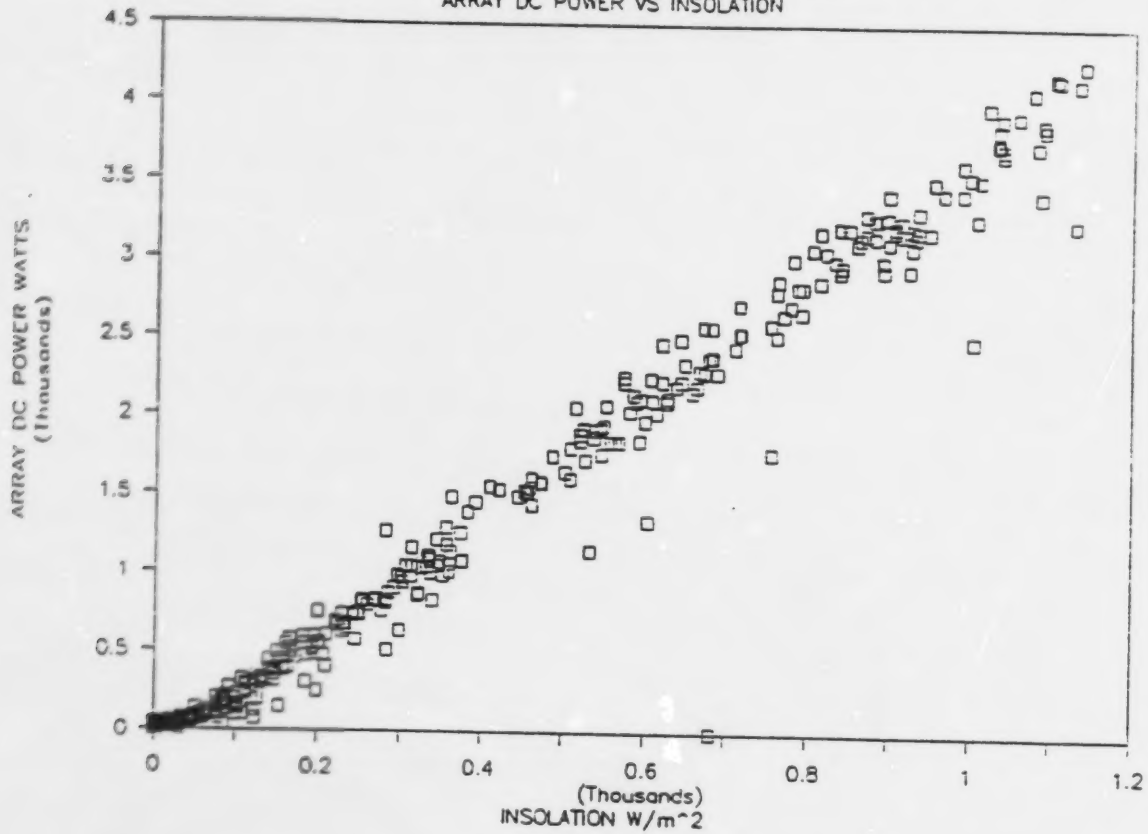
WHILE THERE IS A NET ENERGY DEMAND FROM THE
UTILITY, THERE ARE MANY HOURLY READINGS
INDICATING POWER BEING FED BACK TO THE GRID.

SLIDE NUMBER 142

Figure C11

KORTRIGHT PV GENERATOR

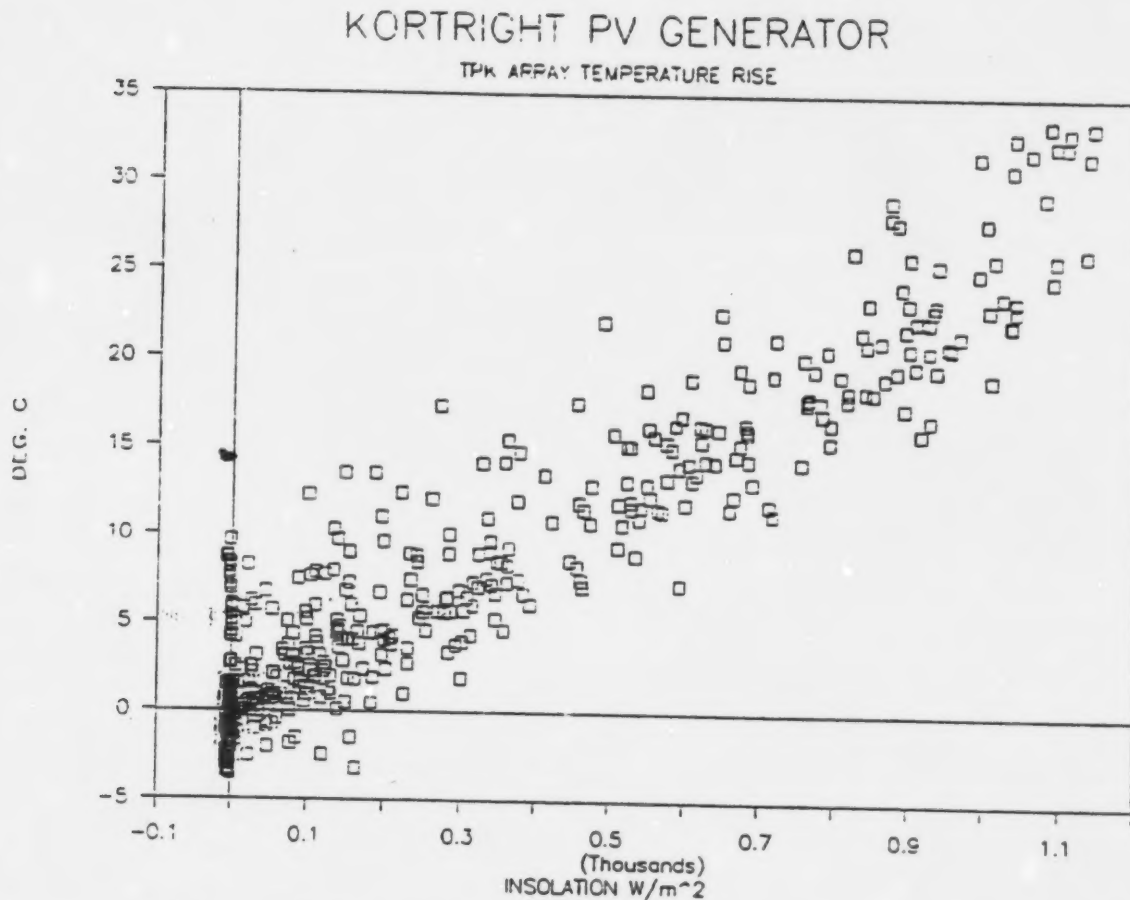
ARRAY DC POWER VS INSOLATION



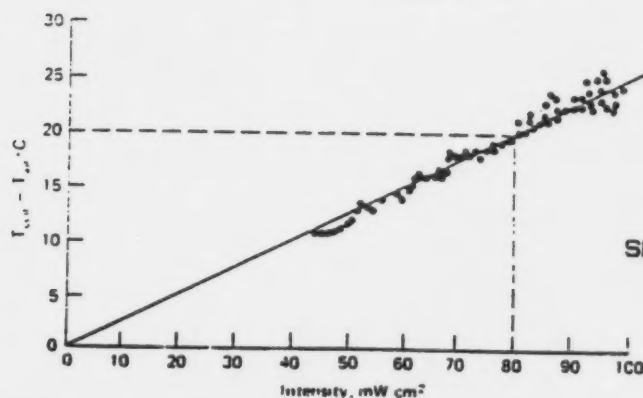
OUTPUT FROM THE PV ARRAY SHOWS A STRONG LINEAR RELATIONSHIP TO RADIATION LEVELS. SOME SCATTER IN DATA MAY BE DUE TO PARTIAL SNOWCOVER ON THE PV MODULES AND A COMPLETELY UNOBSTRUCTED SOLARIMETER.

SLIDE NUMBER 143

Figure C12



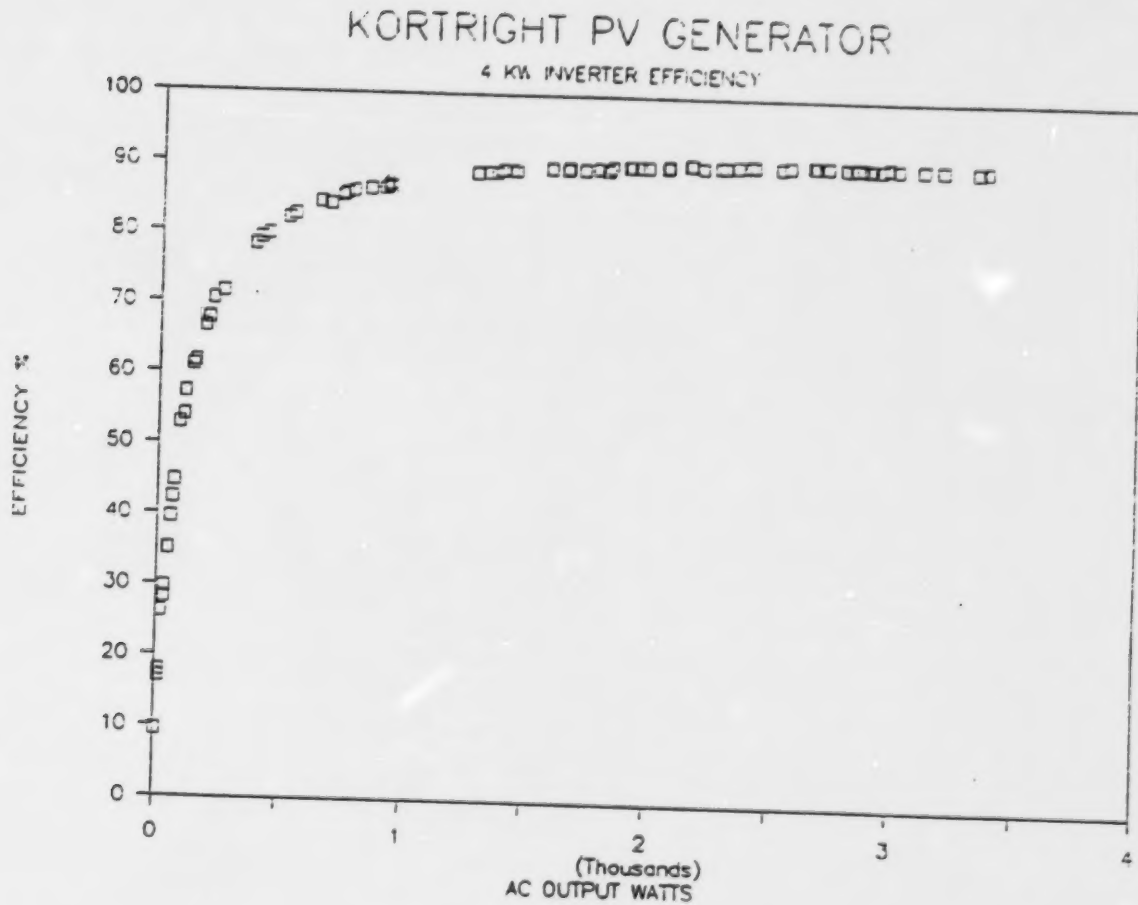
THE TEMPERATURE RISE OF THE PV CELL ABOVE AMBIENT TEMPERATURES CONFORMS TO THAT FOUND BY OTHER RESEARCHERS (SEE FIGURE BELOW). THE RISE IS TYPICALLY 20 CENTIGRADE DEGREES AT RADIATION LEVELS OF $1 kW/m^2$.



SLIDE NUMBER 144

Figure 4-8 Solar-cell minus ambient temperature versus insolation. (Low Cost Solar Array Project, Block IV Solar-Cell Module Design and Test Specification for Residential Application, Jet Propulsion Laboratory, Pasadena, Calif., 1978, p. A3.)

Figure C14

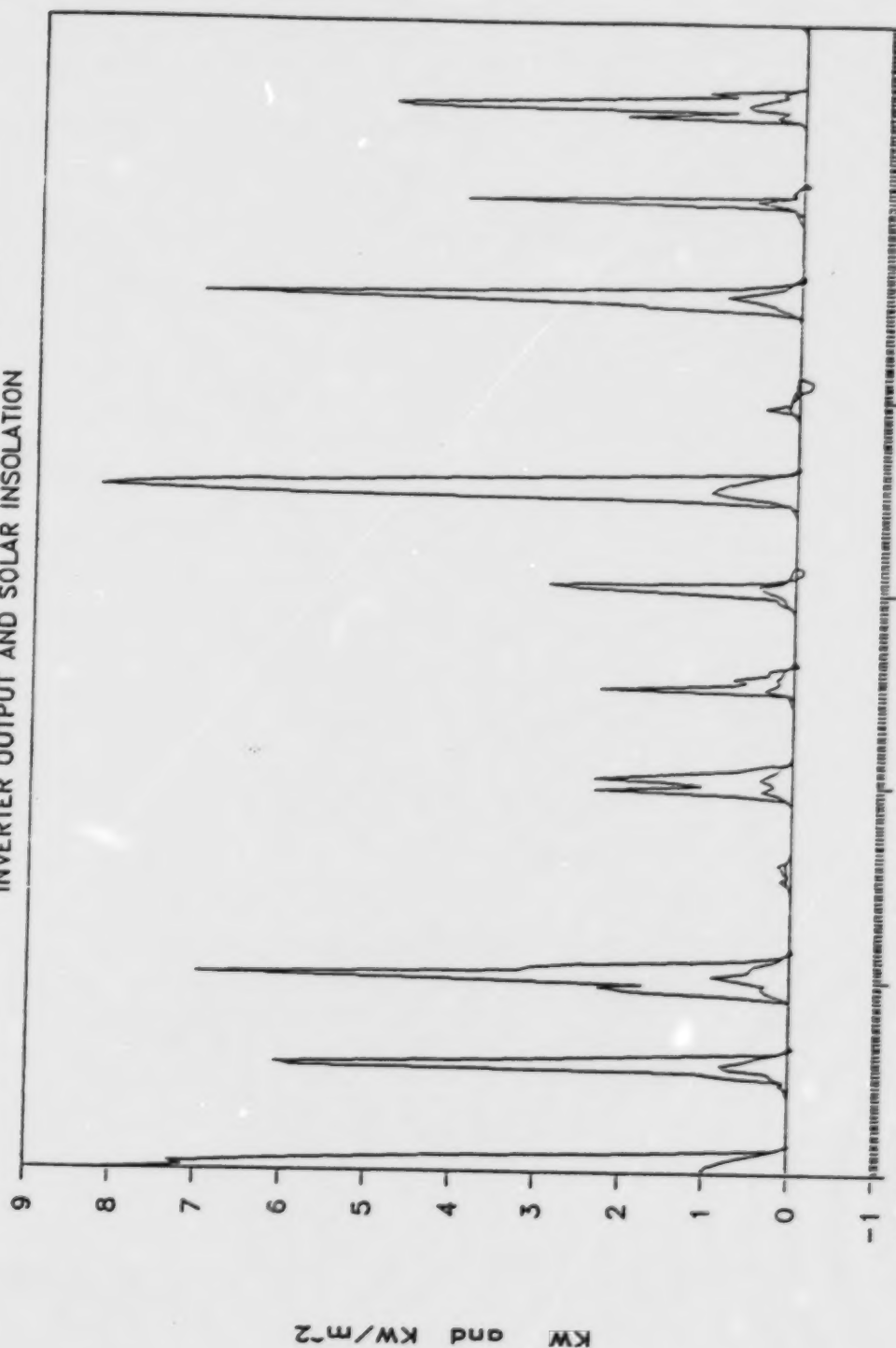


THE INVERTER REACHES MAXIMUM EFFICIENCY OF ABOUT 90 PERCENT
AT ONE QUARTER OF ITS RATED MAXIMUM OUTPUT OF 4 kW.

SLIDE NUMBER 145

BIG TROUT LAKE PV GENERATOR

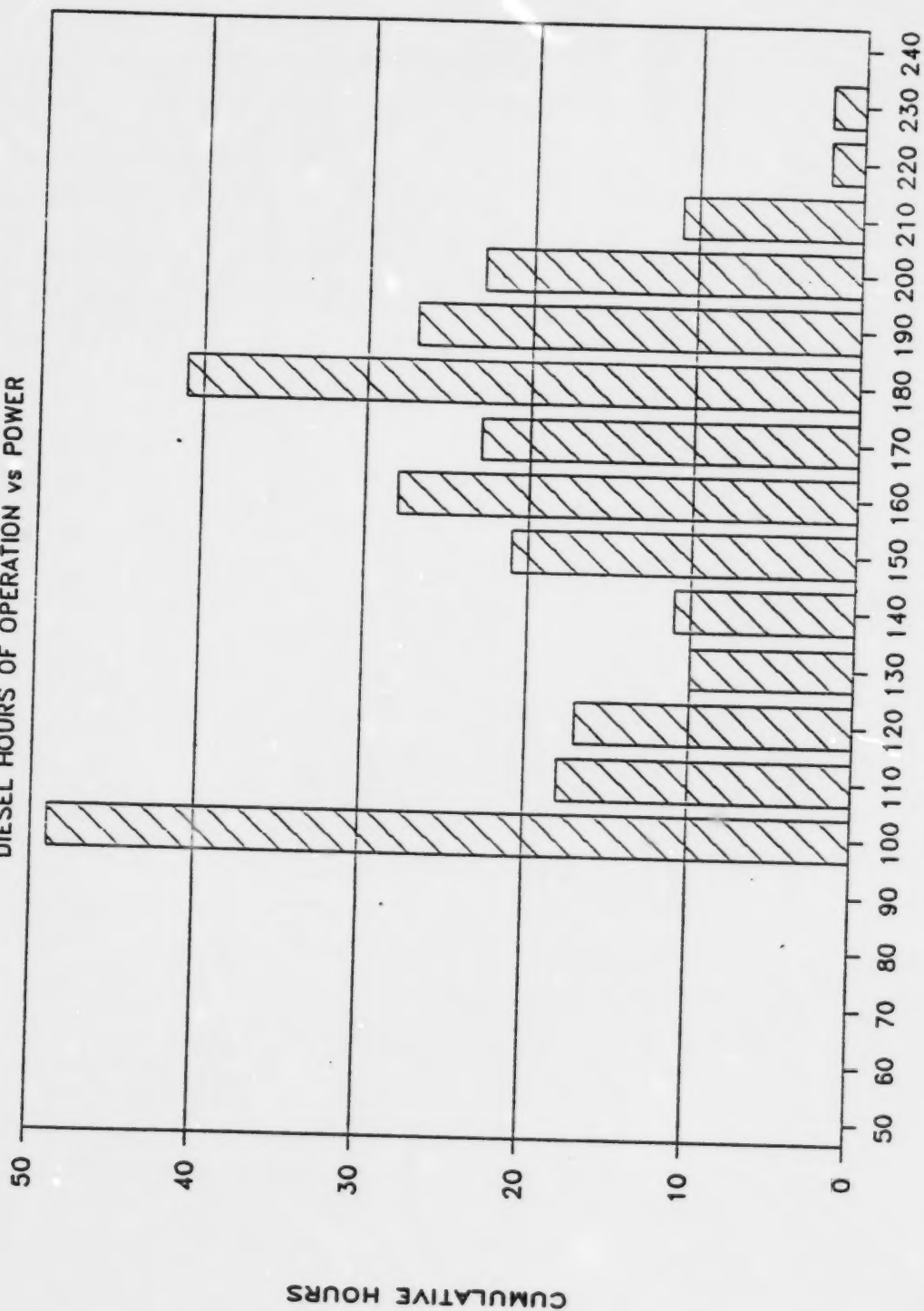
INVERTER OUTPUT AND SOLAR INSOLATION



19 SEP 86 21 SEP 86 23 SEP 86 25 SEP 86 27 SEP 86 29 SEP 86
 INVERTER INSOLATION
 SLIDE NUMBER 148

BIG TROUT LAKE PV GENERATOR

DIESEL HOURS OF OPERATION vs POWER

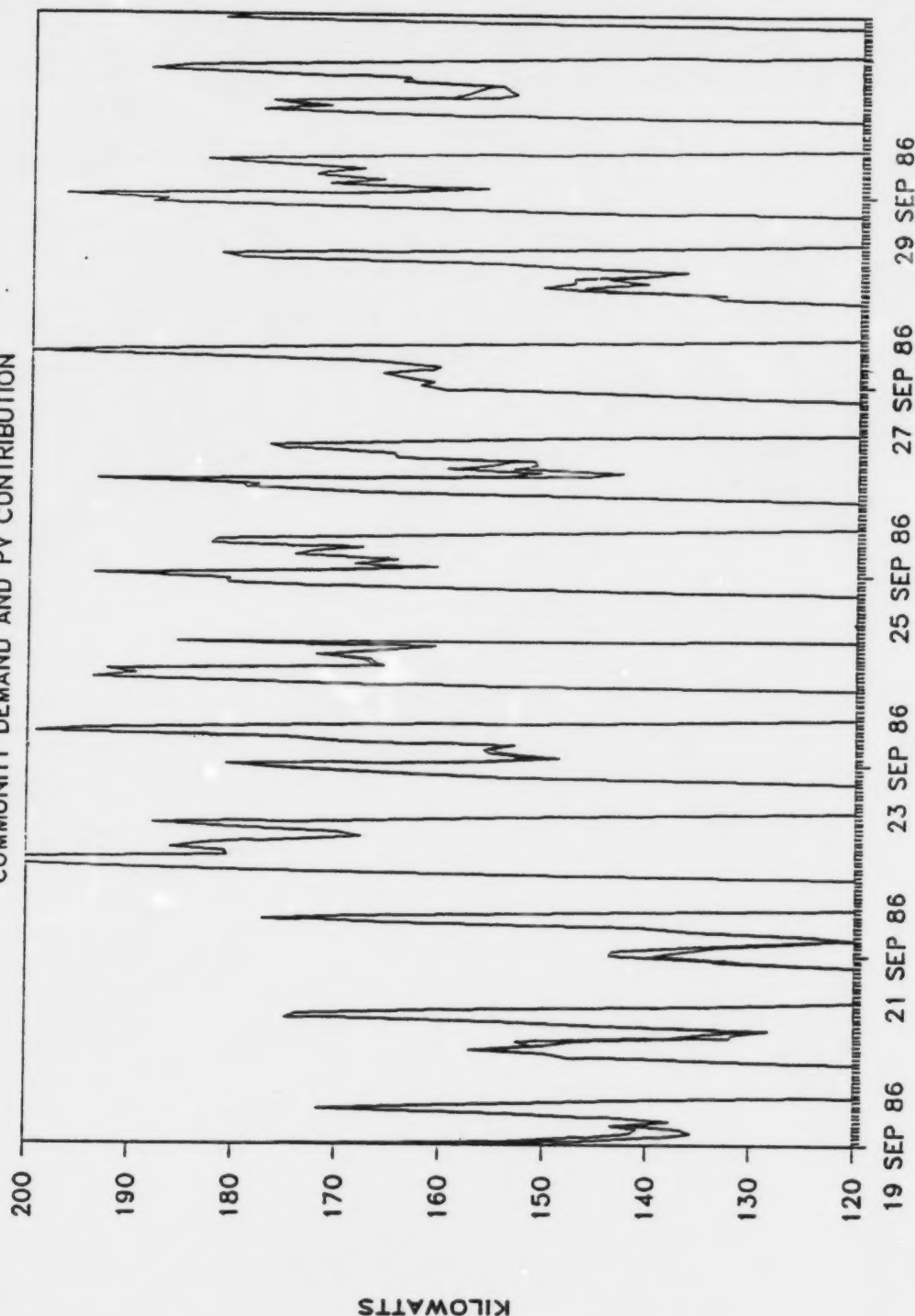


KILOWATT OUTPUT OR LESS

SLIDE NUMBER 149

BIG TROUT LAKE PV GENERATOR

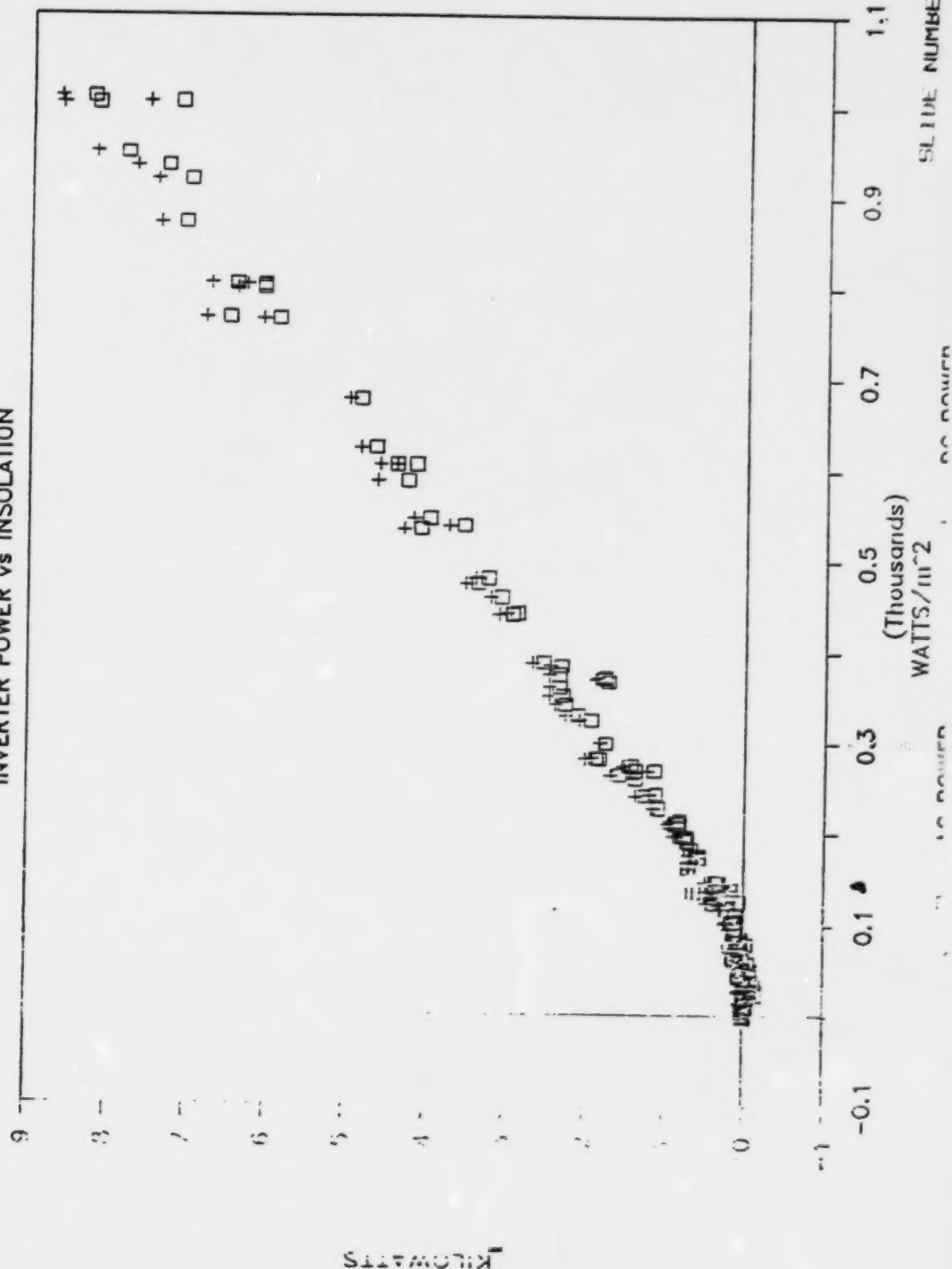
COMMUNITY DEMAND AND PV CONTRIBUTION



SLIDE NUMBER 150

BIG TROUT LAKE PV GENERATOR

INVERTER POWER vs INSOLATION



TECHNOLOGY FORECASTS

- DR. RAYE THOMAS

(Dr. Thomas is president of TPK International, an Ottawa based firm manufacturing PV modules and production equipment)

Kicking off this part of the presentation, let's get away from systems for a while and talk about technology.

Don mentioned that you have heard all sorts of predictions, and typically, when we look at the way the predictions go, one expects a product to go from the discovery point and gradually grow until it reaches maturity, and perhaps after that, it's replaced with something else.

The photovoltaic scene has come along in the second group here, where there's lots of grand predictions as soon as the technology is discovered, and then, all of a sudden, you find there are problems. Then you don't hear very much until the problems are solved, and then you go through the normal type of growth.

Many of the technologies that I'll discuss today later on in the talk, I'll show where they fit on this particular type of product-growth curve.

---SLIDE NO. 152

The technologies that we're looking at are shown here. The first several technologies, six of them, are silicon technology. I discussed silicon technology this morning, but it's worth looking at them: the single-crystal silicon; polycrystalline; microcrystalline, which means very small crystals; ribbon, which is still crystalline technology; amorphous silicon, which is the one that gets most of the hype and that, of course, is a disordered material. Then we've got a multi-junction cell, which is amorphous silicon plus other things.

Then you've got the other ones which I consider as being really the only contenders for photovoltaics at this point: gallium arsenide, which has certain applications: cadmium telluride; cadmium sulfide; and copper indium

diselenide with cadmium sulfide.

Many dead ends have been pursued in other technologies, so I will not mention those particular dead ends. Just to finish off the scene in terms of silicon technology, there are still advances to be made in the silicon technology.

---SLIDE NO. 153

I mentioned the techniques for preparing solar cells this morning. The typical route is this left-hand route, where you have a high-temperature diffusion. You will automate the process as much as possible to bring the cost down. You will introduce technology to bring up the efficiency.

There's another approach over on the right-hand side, which is looking at techniques to replace the high-temperature diffusion. As soon as you eliminate some of the high-temperature effects during the process, you will improve the quality of the material, so you can do a colder-temperature process, a quick thermal anneal which anneals only the top surface of the material. You can get an improved performance for the solar cell and potentially lower cost because you can make it on a line-to-line type of production basis.

Then you go to contacting, processing. It becomes the same type of technology later on. I think we've gone roughly as far as we can go in terms of identifying those production techniques.

---SLIDE NO. 154

The efficiencies that you'll probably get in production are up to about sixteen percent, not the theoretical efficiencies, but the records have been run up to twenty percent at the moment. Sixteen percent in production will give you a good module around fifteen percent overall, and that is a significant cost benefit in terms of the amount of power that you can get out of it.

---SLIDE NO. 155

The amorphous silicon approach: Here are the reasons for going to it. It's basically a thin-film version, so you use less material. Obviously, it's a lower cost. The

atoms are random, so it has certain disadvantages.

However, one of the big advantages is that, because of this structure, it has a better absorption in the visible spectrum. Therefore, you don't need a thick layer of material as you do in the single-crystal cell.

But you also have a problem that the light carriers will be lost if you don't collect them very quickly. From a very short distance, you lose them, so you have to make it a very thin layer.

The application at the moment is mainly in the consumer market, but there are cost objectives for the 1990's which suggest that they could be used on a large scale in central generators or on rooftop applications, but there are problems to be overcome.

---SLIDE NO. 156

The two types of structures that are illustrated here: On the left here is a technique which is being pushed by Energy Conversion Devices (ECD), particularly. You have a roll of stainless steel material and do a roll-to-roll deposition process. You have to make, in this structure, in order to get your electric field, a P+ region and an N region, separated by, essentially, and intrinsic region.

Then you have a built-in electric field, so you generate your current carriers in this region and you can collect them because they're swept through by the field and not allowed to recombine as they would normally do if there is no electric field present.

Then, at the other side, you do the deposition of this layer, several depositions, and finally put on a conducting glass of some sort. Indium tin oxide is typically used.

On the right-hand side is the other approach. You would laminate that module the same as you would any other module, the glass surface on top of this.

For the type two version, you do your deposition on the glass, and that glass becomes the front of the module. You put your indium tin oxide on first, and because you go into some high temperatures, typically, in the process, you put a thermos layer, which protects that

indium tin oxide, and then you go through your P+, intrinsic layer, N, and so finally, you would laminate that in the same way that you would in a typical module that you see here.

---SLIDE NO. 157

Now, one of the advantages of making a thin-film module is that you get the module all in one shot rather than a single solar cell. You come up with an approach that's represented here where it's interconnected.

You've got your transparent conducting material, your amorphous silicon, and then metal here, so you've basically got contact with both sides of the device, and you're going from one device here to the next device, working your way through and you can get full-voltage modules all in one shot, which needs only lamination and not the interconnecting process.

Now, I'll say something about efficiency of those modules a little bit later, but first I wanted to just comment on the other options of materials because there are going to be adaptations to that particular approach.

---SLIDE NO. 158

Here's the typical curve that's been used in selecting materials for making solar cells, an efficiency curve calculated so that you can get lists of materials in terms of energy band.

Now, if we look at silicon, it's far from being the optimum material for solar cells. However, if you make it amorphous silicon, you push it over toward the peak of the curve and you have a much better value there, better absorption.

The gallium arsenide, you find, is roughly in the right category. Cadmium telluride is another material that fits that market. It's a very nice material for making solar cells.

Copper indium diselenide, which is the other material I mentioned, would be slightly off the peak, but nevertheless, it's reasonably close, and it's a good material for thin-film solar cells.

The gallium arsenide one has the potential for the highest efficiency, but as far as terrestrial applications are concerned, forget it. It's too expensive to even worry about it. If you're using a concentrator solar cell, very high concentration, then, fine. Use it for that application.

Otherwise, the greatest application is for space, so if anybody's in space, that's the material I would look at because it has better radiation characteristics than most of the other materials; in particular, better than silicon. You can get a much higher power-to-weight ratio when you're flying in space.

I won't dwell on the gallium arsenide solar cell other than to say that it has the application for space, the concentration. It can be made in thin-film layers the same as the cadmium telluride and the amorphous silicon.

---SLIDE NO. 159

Now, we find that, when we make the amorphous silicon solar cells, there's a bit of a problem because it's a disordered material. You find very often that there are dangling bonds associated with the silicon voids in the material.

You try to satisfy those voids by putting in hydrogen atoms. Some people will try to use fluorine with no noticeable real effect.

The bonds can be unstable, so once you shine a light on the device, you may make a device with a high efficiency, but light on the device causes those bonds to break and the efficiency degrades over a period of time.

It's possible to make relatively stable devices in the order of four to six percent at this point in time, and it's those devices that are the ones that you find in calculators and wrist watches -- mostly consumer applications.

Put them out in the field in the bright sunlight and they'll degrade, so at this point in time, it's not a device for remote, stand-alone applications, but in the future, it has to be.

One of the ways people are finding in terms of improving

the performance, getting better results, is to go to a cascade type of solar cell. Rather than simply make an amorphous silicon solar cell, string several materials together, several devices together.

---SLIDE NO. 160

Here is an approach to terminal cascade solar cells. You would use amorphous silicon -- this is the symbol here for amorphous silicon; the "H" simply means it's hydrogenated -- you might find a material like amorphous silicon carbide, amorphous silicon germanium, to give you a different band gap, a wider, larger band gap in the material. Therefore, a lot of the sunlight will shine through.

Here, we have a high band-gap material used in this top region. Some of the light's absorbed, the high-energy light, but most of it passes through, so you make one device to collect a certain part of the solar spectrum. You make a heavily built P region and a heavily built N region, connect it up to a terminal junction so the carrier can easily pass through that. Then this next device will be a standard amorphous silicon, so you have the two of them strung in series. You get higher voltage, you collect a higher proportion of the solar spectrum, and you also get a higher efficiency device.

It also looks to be a much more stable device. I'm not sure of the reason. I don't think anybody here is sure of the reasons for this ability, but they are turning out to be more stable.

A second approach, which is one that Arco introduced fairly recently, is a four-terminal device shown on the right-hand side, where you make one device of a high band-gap material as one separate module and then you optically interface it with another material. They've done it with amorphous silicon and the bottom one with copper indium diselenide. You can get a fairly high-efficiency module that way.

These seem to be the approaches that are being developed, and if we look at some of the efficiency results, bear in mind that the predictions are that you need roughly a ten percent efficiency for it to be economically feasible on a commercial basis.

---SLIDE NO. 161

You will see some of the efficiencies that have been achieved in small-area devices, and typically, if you look at the upper curve, the heterojunction or stacked-cell approach is the one -- or cascade cell; all three terms are used interchangeably -- that's the one that gives you the high efficiency.

The lower-efficiency devices, the standard amorphous silicon ones, tend to be congregated down here around the six percent level, even though people have reported over ten percent on single amorphous silicon cells.

---SLIDE NO. 162

In fact, if you look at some of the players in the game, if you look at these devices, typically, you've got silicon carbide and amorphous silicon. These are basically stacked-junction cells or heterojunction cells. You see open-circuit voltages are very high. Comparing those to the standard single-crystal silicon devices, the open-circuit voltages there were over six hundred millivolts; here, they're over eight hundred millivolts.

The short-circuit current, another factor, for single-crystal devices was up around forty in terms of the high-efficiency devices. Here, you're approaching twenty.

Fill factors are roughly comparable to the best ones in the single-crystal devices. They're up over eighty percent, but the efficiencies here, as you can see, are down, 9.7 to 11.5, as compared to the best one for silicon, around 20 percent.

You can see that's small-area devices. None of the large-area modules have yet anywhere near these sorts of figures. However, I'm confident that they will in the future.

---SLIDE NO. 163

If we look really at technology forecasts for amorphous silicon -- Don mentioned Paul Maycock earlier on -- here's the sort of technology forecasts that he uses in terms of amorphous silicon solar cells.

Efficiency now -- this is in '85 -- is in the six percent; 1990, projected nine percent. That corresponds with Sanyo's figures for projections to 1990, 1991. They figure that nine percent stable solar cells at that point in time will give them a commercial product which can go after the large-area market.

Going up to about 1995 with module efficiency, because you don't lose too much in this area, brings us down to about eight percent in 1990 and ten percent in 1995.

The warranties at the moment: I'm surprised that even a year is used as a warranty factor, but obviously, that warranty period will go up and approach the warranty currently to be found on the single-crystal module, which is now on the order of five years or ten years.

---SLIDE NO. 164

Here are the projections on manufactured prices. You see those going down. The profitability price, obviously, will go down as well.

---SLIDE NO. 165

In summary, that's the materials summary. You've got the elemental semiconductors that have been looked at. Only silicon has any prospects in various forms. Compound semiconductors: gallium arsenide will give you solar cells around sixteen to nineteen percent now. Potentially, in a cascade type of cell where it can carry the material by different deposition techniques, you can get it over thirty percent for a solar cell.

The binary compounds: Cadmium telluride and cadmium selenide are the prospects, but I think cadmium telluride is the winner.

Ternary compounds: Copper indium diselenide is probably the only one that has any real prospects.

---SLIDE NO. 166

Now, I've put them on a growth curve. We did this a few months ago. They may have changed very slightly, but if we look at that growth curve again, we can see that cadmium telluride is in the early stages; probably, up

around here at this stage. Multi-junctions are coming up in the growth predictions.

You can see the amorphous silicon is sitting down here -- or the thin film -- at the moment, but as the problems are solved, it will start going up the growth curve. The single-crystal silicon is far ahead of the others in terms of its growth to maturity.

---SLIDE NO. 167

The Japanese approach, looking only at that growth phase, here's where the silicon technologies all are. This was done at the beginning of 1984, so you see how they fit. Here's a slide over to the right or left, depending on how fast the growth is going on.

---SLIDE NO. 168

Finally, 1990, again, Paul Maycock: the world market percentages, and he's looked at the different technologies. The single-crystal silicon: the cell efficiency is about sixteen percent; module efficiency, about fifteen percent; and the price, about \$3.00 per watt. These are U.S. dollars.

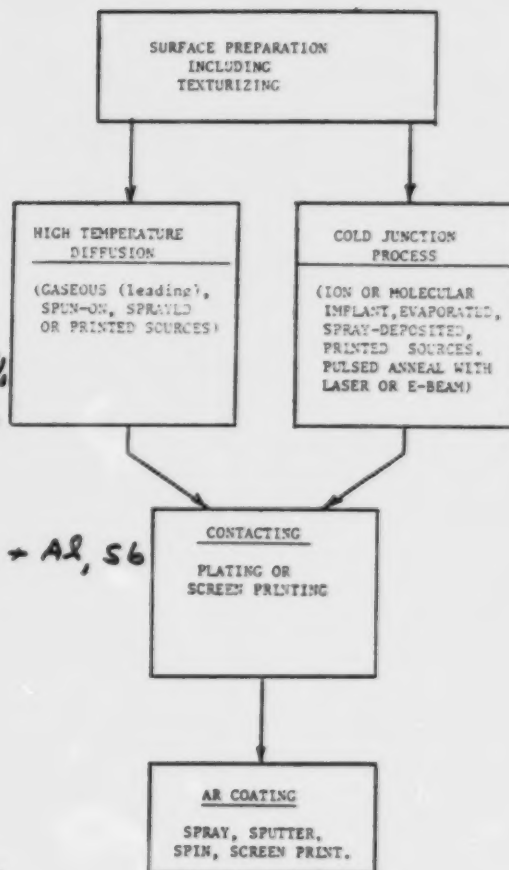
Semi-crystalline silicon will have thirty to forty percent of the market still. Polycrystalline silicon coming up closely behind, but lower efficiency because of the grain boundaries.

Ribbon materials: similar sorts of efficiencies; it has imperfections. Amorphous silicon: perhaps around ten percent. I think that's consistent with the earlier curve I showed you. The other ones are long shots and they get about five percent of the market.

The technology is obviously developing. The problems are being solved all the time. They're not being solved as fast as the original projections, but in the 1990's, it looks very positive for the thin-film materials and for the cost of photovoltaics.

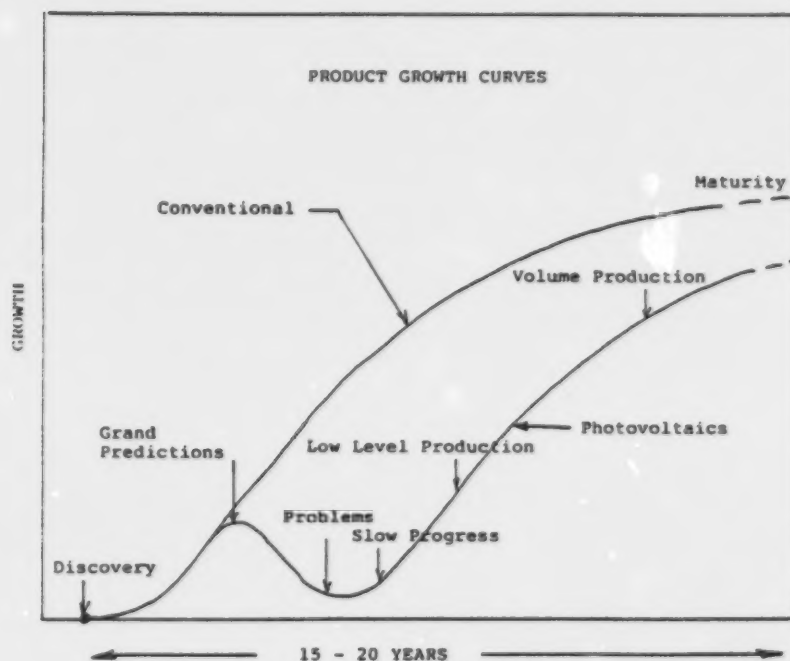
PV Technologies

Si Based {
 Single crystal Silicon
 Polycrystalline Silicon
 Microcrystalline Silicon
 Ribbon Silicon
 Amorphous Silicon Thin Film
 Multi junction cells - a.s.c.
 Ge As
 Tandem junction Ge As + Al, Sb
 CdTe/CdS
 CuInSe₂/CdS



SLIDE NUMBER 152A

FIGURE 5. OPTIONS FOR SILICON SOLAR CELL PROCESSING.



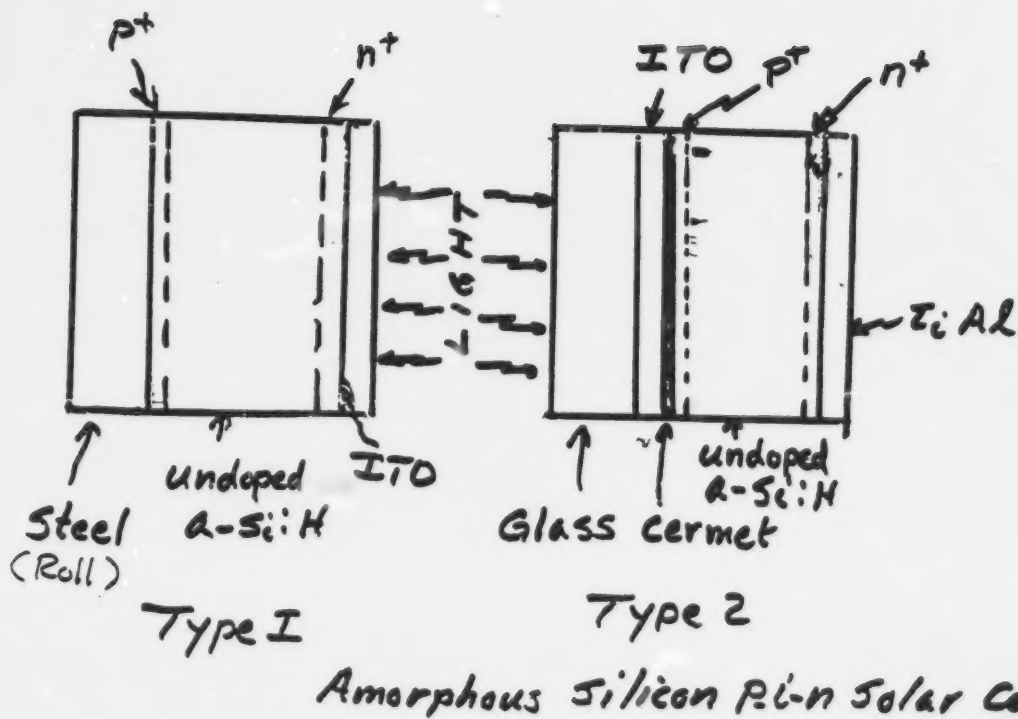
SLIDE NUMBER 153

SLIDE NUMBER 152

AMORPHOUS SILICON SOLAR CELLS

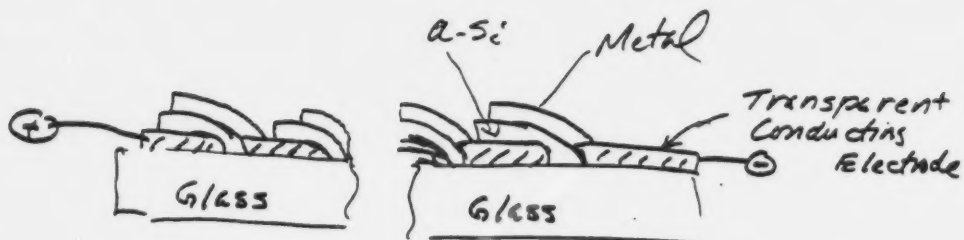
- THIN FILM VERSION OF SILICON SOLAR CELL
- ATOMS RANDOM
- BETTER ABSORPTION IN VISIBLE SPECTRUM
- LIGHT GENERATED CARRIERS LOST IN SHORT DISTANCE,
HENCE NEED FOR THIN FILMS.
- LITTLE MATERIAL REQUIRED
- CAN BE DEPOSITED ON CHEAP SUBSTRATES OR SUPERSTRATES
- NOW IN USE IN CONSUMER ELECTRONICS MARKET
- GOALS: GREATER THAN 10% EFFICIENCY BY 1990
COST IN \$0.15 - 0.40/W_p by 1990.

SLIDE NUMBER 155



SLIDE NUMBER 156

Integrally Connected a-si Cell



SLIDE NUMBER 157

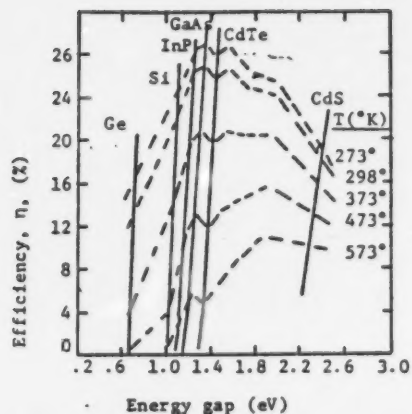
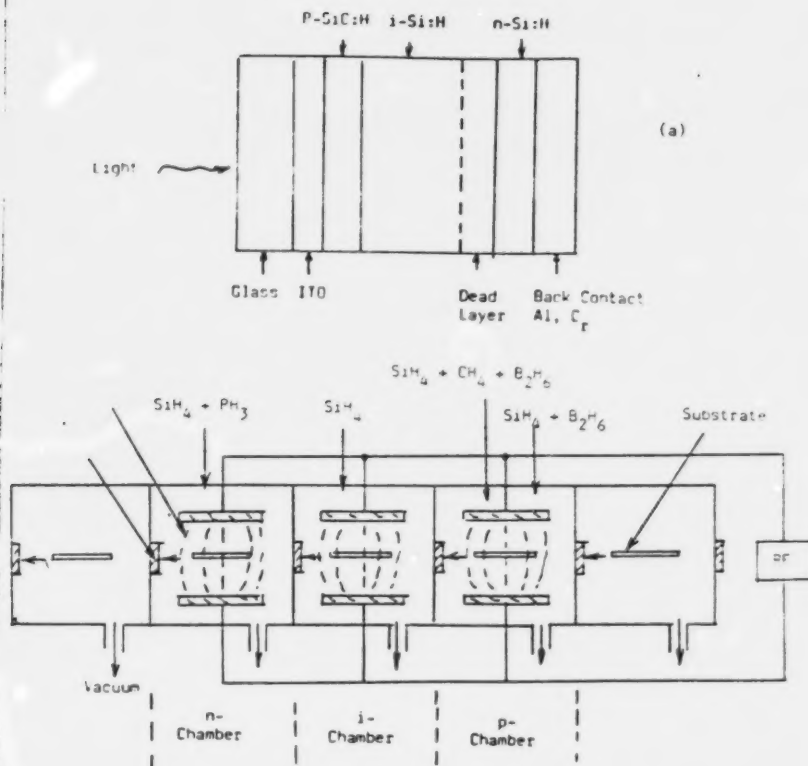


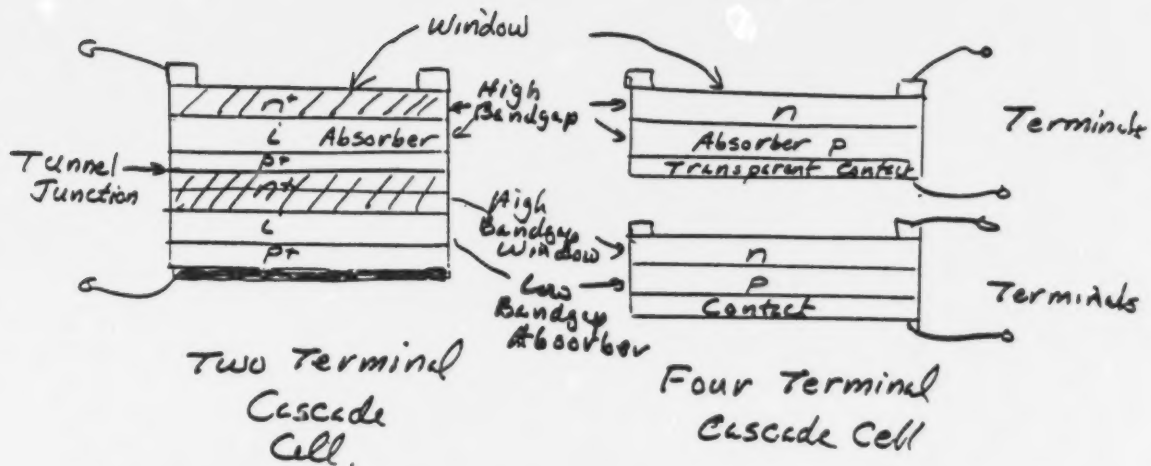
Figure 9. Behaviour of efficiency with temperature [23]
Wysocki and Rappaport [23], Courtesy American Institute of Physics.)

SLIDE NUMBER 158



(a) CROSS SECTION OF a-SiH/a-SiC:H SOLAR CELL
 (b) SEPARATED REACTION CHAMBER USED BY KUMANO ET AL IN GLOW DISCHARGE PREPARATION OF AMORPHOUS SOLAR CELLS

SLIDE NUMBER 159



a-Si:H
 a-SiC:H
 a-Si_{1-x}Ge_x:H

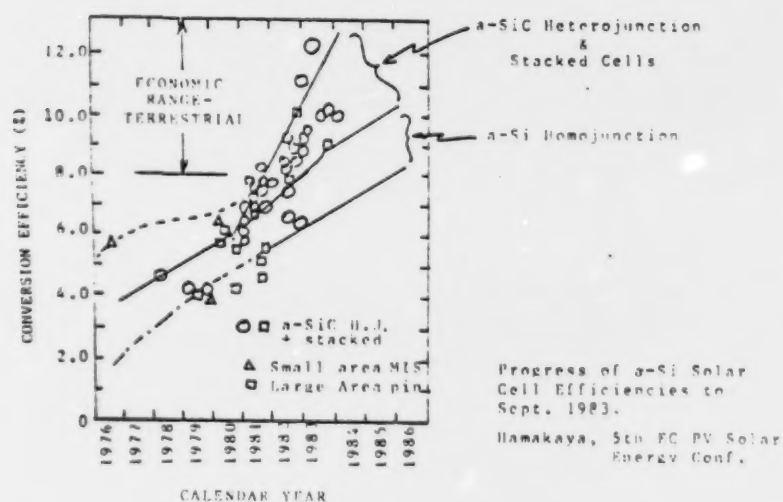
a-Si:H
 a-SiC:H
 a-SiGe:H
 CuInSe₂

SLIDE NUMBER 160

PERFORMANCE OF BEST REPORTED a-Si CELLS

Structure	V _{oc} , mV	J _{sc} , mA/cm ²	FF	Efficiency, %	Area, cm ²	Manufacturer's
Glass/TCO/p(a-SiC:H) i-n(a-Si:H)/Ag	869	18.9	73.0	11.5	1.00	Sanyo Electric (Ref. 4)
Glass/TCO/p(a-SiC:H) i-n(a-Si:H)/Me	864	17.6	73.0	11.1	1.0	Fuji Electric Co. (Ref. 5)
Glass/TCO/p(a-SiC:H) i-n(a-Si:H)/Me	840	17.8	67.6	10.1	1.09	RCA (Ref. 3)
Glass/TCO/p(a-SiC:H) i-n(a-Si:H)/Me	850	16.1	71.0	9.7	4cm ²	ARCO Solar Inc. (Ref. 6)

SLIDE NUMBER 161



SLIDE NUMBER 162

TECHNOLOGY FORECAST FOR a-Si

(1984 \$) AFTER MAYCOCK

	1985	1990	1995
4" x 4" CELL EFFICIENCY (%)	6	9	12
MODULE EFFICIENCY (%)	5	8	10
AREA YIELD (%)	50	70	90
WARRANTY (YEAR)	1	2	5
MANUFACTURED COST (\$/Wp)	3.00-4.00	1.20-1.80	1.00-1.50
PROFITABLE PRICE (\$/Wp)	5.00-6.50	2.00-3.00	1.66-2.50

MATERIALS SUMMARY

1. ELEMENTAL SEMICONDUCTORS

- . ONLY SILICON HAS PROSPECTS
- . SINGLE CRYSTAL, POLYCRYSTAL, MICROCRYSTAL AND AMORPHOUS FORMS
- . PRESENT, NEAR, AND FAR TERM PROSPECTS.

2. COMPOUND SEMICONDUCTORS

III-V COMPOUNDS: GALLIUM ARSENIDE

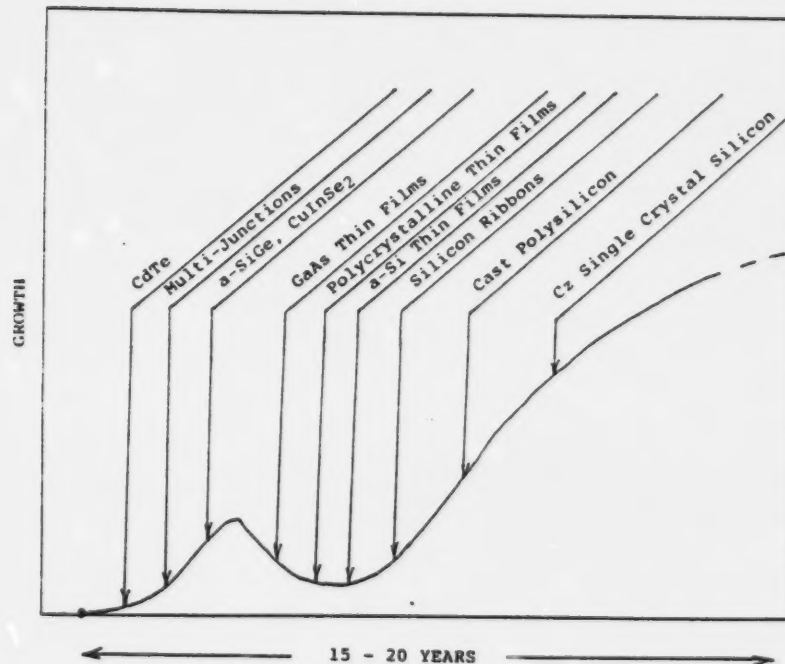
- . PRIME CANDIDATE FOR CONCENTRATION AND SPACE
- . PRESENT (16-19% EFF), NEAR TERM (21-25%), FAR TERM (OVER 30%).

BINARY COMPOUNDS: HETEROJUNCTIONS OF CdTe/CdS and CdSe/CdS. LONG TERM PROSPECTS.

TERNARY COMPOUNDS: HETEROJUNCTIONS OF CuInSe₂/CdS.
OTHERS?
LONG TERM PROSPECT

SLIDE NUMBER 165

TPK SOLAR SYSTEMS INC.



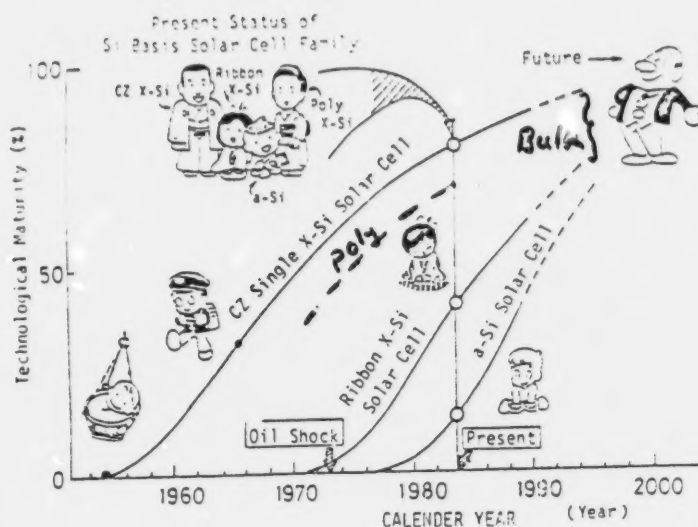


FIG. 1 - SILICON TECHNOLOGIES

SLIDE NUMBER 167

TPK SOLAR SYSTEMS INC.

TABLE 2. 1990 PV TECHNOLOGY FORECASTS

- AFTER PAUL MAYCOCK ²

TECHNOLOGY	% WORLD MARKET	CELL EFFICIENCY %	MODULE EFFICIENCY %	MODULE PRICE \$/WATT
SINGLE CRYSTAL SI (INCLUDING CELLS FOR CONCENTRATORS)	30-40	16	15 (SQUARE CELLS)	3
SEMICRYSTAL SI	> 25	15	14	2
RIBBON OR SHEET SI	15-20	15	14	2
AMORPHOUS SI	20*	10	10	1
THIN FILMS OTHER THAN SI	5**			

* DOMINATE ROOF MARKET IF STABILITY NOT A PROBLEM.

** MARKET RELUCTANCE TO TAKE RISK ON UNPROVEN MATERIALS.

SLIDE NUMBER 168

MODULE VENDORS

Note: The format, for the module vendors' presentations was the following. Five minutes was allotted to each of six vendors who had expressed an interest in presenting their company, their product, and their services that they can offer to the PV community. The order was randomly selected.

A.E.G. CORPORATION - MR. WALTER J. O'NEIL

Regional Manager
Photovoltaic Systems
Building 3, Suite 130
2222 South Dobson Road
Mesa, Arizona 85202-6481
602 - 897-0091

Mr. O'Neil: Thank you. I appreciate being here today. A.E.G. Corporation is a division of Daimler-Benz, a multinational. We were recently purchased by them in November of last year.

We have been involved in the photovoltaics industry since the middle 1960's, originally in space, and we are still involved in space. We are one of the unusual manufacturers that manufacture all our own power components as well as being involved in space.

We have eighty-four satellites deployed with our power systems on board. We manufacture not only the modules but the charge controllers, the inverters, and any of the other controllers that are needed.

A.E.G. has had a hundred and seven years experience in manufacturing DC switch gear. "A.E.G." means All Electric Germany. We have our manufacturing plants in fifteen countries, but our photovoltaics portion is manufactured in Baden, West Germany, as well as Heilbronn.

As far as the terrestrial use is concerned, we have been designing and installing turnkey systems throughout the

world since 1973. We have systems in fifty-two countries.

We are an electrical and electronics manufacturer, and photovoltaics and the power components are just another electrical device that we're manufacturing. Our products catalogue is 12,000 to 13,000 items.

The modules that we manufacture: We're using a polycrystalline cell. We manufacture modules from one and two watts, which come in four, six, and nine-volt capacities. We have a 2-watt module -- now, these are consumer items -- that are in six, nine, and twelve-volt capacity. We have our standards, which are the ten, twenty, and forty-watt modules. Our modules in the ten, twenty, and forty-watt are a little different than you've seen up to this point.

On our polycrystalline cell, we use a vapour deposition process as opposed to screen printing that you've seen mostly today. We use a silver aluminum grid vapour deposition process. We use e.v.b. as opposed to e.v.a. in our sandwich, and we have glass in the front and glass in the back, our idea being that, with glass on both sides, we probably have a little more environmental protection than you would normally have with a Tedlar back.

We use a stainless steel frame as opposed to an aluminum, and the market that we're looking for is really a commercial market. Let me show you one of our -- it just happened to fit in my briefcase, but this is our two-watt module. This is normally sold through catalogues, and I don't really have a great deal to do with it, but it fits in the briefcase nicely.

We have a foldable module that we use for the military. This happens to be a 10-watt. This is used for back-packing and for soldierly items. We also have a 20-watt, 12-volt and 24-volt.

Hopefully, you saw some of our specification sheets out front. Our twenty and forty are all glass on glass, but our 10-watt module, we happen to make specifically for a harsh environment. It also has a stainless steel back so that they can be walked on. shot at, whatever they need to be.

We have a quarterly solar report that comes out specifically on PV. If you would like to get on the mailing list, give me your card and I'll be happy to include you. Thank you.

TPK INTERNATIONAL - DR. RAYE THOMAS

36 Bentley Avenue
Nepean, Ontario K2E 6T7
613 - 225-4403

Dr. Thomas: Just to give you a bit of background on TPK, we started in 1979 as a research and development organization capitalizing on the R and D that was being done at Carlton University and at the University of British Columbia.

We started module production in 1981 and, in fact, the first modules that were ever done by us were installed at Atikokan. We've come a long way since that particular time.

We started equipment manufacturing in 1984 and that's become the mainstay of the organization. We provided turnkey production to India in 1985, and China will get the last of their equipment in 1986.

We manufacture equipment here for automatic screen printers designed for solar cell production. The solar cell tester and sorter -- once you've made them, you want to test them and sort them for use in modules. Laminators, module testers-- that's a list of the type of equipment.

As backup, we also manufacture solar cells. We have a pilot plant in-house manufacturing at 250-kilowatt capacity on a single-shift basis.

That's for the Canadian market and we intend to do Canadian projects. We're not going head to head with A.E.G., for example, on the international market.

For system size, we make, as I said, single-crystal cells with an average efficiency of 12 1/2 percent. This was demonstrated through our customers. The spread is ten to fifteen percent.

We're going to be doing poly-cells in early '87. The

modules are in the 10 to 55 watt range, depending very much on whether the cell is a circular cell or a square cell and what the efficiency is and whether these are half cells.

We make a line of voltage regulators which we offer. We have maximum power trackers, particularly for water-pumping applications. We do two versions: a DC to DC converter, which we do for low-power applications, and an array switcher, which allows you to identify each individual module and switch them into different configurations, depending on whether you'll need lots of current or lots of voltage.

We do water purification systems. We're developing that. We've gone past the first prototype stage. We're at the second prototype stage. That will shortly be offered.

Water pumping systems: We have three systems. We've done airport beacons. Again, we can offer a complete package. We've done ten of those systems.

Finally, we offer a computerized system-design package, which we use ourselves in-house for sizing systems for customers, but we've also sold that to some of our customers internationally as well.

---SLIDE NO. 169

Just to give you some pretty pictures of the equipment, here's the type of equipment that we use in the production line. This is our automatic screen printer. We have sent solar cells in cassettes through a printing operation. You can see the cells, the wafers, coming out here at the bottom.

They're oriented. Then they're screen printed. Then they're sent on to a belt furnace for either drying the material or alloying the contacts into the solar cell.

---SLIDE NO. 170

They come out two by two. This is a fairly unique design system. The whole line is done that sort of way.

---SLIDE NO. 171

We make laminators. Here is the type of laminator we

supply to India and to China. These are where you actually encapsulate the solar cell in a vacuum system with pressure and temperature.

---SLIDE NO. 172

The latest version which is being shipped next week to the Netherlands is this unit, which is a fully microcomputer-controlled version which is designed to be allowed to be fed into a central computer-controlled production line.

---SLIDE NO. 173

Here's a module tester that we make.

---SLIDE NO. 174

If you want clean sheets of glass, we offer a nice little glass cleaner.

---SLIDE NO. 175

Our pride and joy: Where you want to test and match solar cells, it's a solely microcomputer-controlled solar cell tester and sorter with a solar simulator on the top, so it's combining two sets oriented, tested, and sorted into categories.

That's what we are.

BESTEK MICRO DEVICES & SYSTEMS INC - MR. NAE ISMAIL

President
Suite 207
Southvale Plaza
2660 Southvale Cres
Ottawa, Ontario
K1B 4W5
613 - 523-5211/7677

Mr. Ismail: What I have here is a number of samples. I think I'm going to be spending most of the time talking about them, but I want to give you a brief outline as to what Bestek is.

Bestek was incorporated about four years ago on the realization that, in the solar industry, there seems to

be a general lack of material for people to use by themselves. Apart from going to manufacturers and buying a finished panel, if you want to build something yourself, quite often you end up very frustrated.

The result of that rationalization was that perhaps there is a market for low-power solar cells. The result of that work is we put together a company called "Bestek Micro Devices" four years ago.

This is the basic building block, which is essentially a four by four inch solar cell reconstructed to give you a voltage that you want. A regular source will give you half a volt but this thing will give you up to eight volts if you want.

We put it behind a piece of glass laminated just like a big panel. You can soak it in water for months and nothing will happen, and of course, at the end, these might come off because of corrosion, but the glass is silicon, and all that is an integral part.

Now, we're selling these things to people, to end-users, to students, to hobbyists, and they can build their own array that way simply by connecting the leads together, soldering them up in strings or in parallel, and they can even mount them on a piece of wood and caulk between them just like a bathroom tile and make a low-cost panel that way.

The other interesting thing is, if anything should happen to your panel, five minutes later, you can replace the one that is damaged and your investment value is protected.

Now, this is glass. We have recently come out with a plastic version of it. The whole thing is about half an ounce. Very lightweight -- you can drop it and it won't break.

To the extent that we thought, well, maybe people don't want to do any work; we'll go one step further. We put it in a little plastic case and they can connect through a whole myriad of battery holders and charge batteries that way. All you have to do is just plug them in and it's assembled.

We also have a slightly more powerful version of this

product, which again is out of the same building block. It's a plastic, projection-moulded case -- more power, higher voltages. We can provide you with anywhere from as low as three volts to as high as twelve volts.

When I refer to the voltages, these are maximum power-point voltages, not the actual open-circuit voltages. The current capability is anywhere from a tenth of an amp to about a quarter of an amp, depending on the voltages. If you go higher in voltage, you sacrifice the current. If you go lower in voltage, you gain on the current. The six-volt package will operate a small hand-held radio or cassette recorder directly without batteries.

Something in the future: Again, the same type of product, but with a battery compartment in there, so all you have to do is put your battery in and close it up and leave it out in the sun.

Apart from making solar products, we also have developed a line of electronic ballast, typically that size, high efficiency, low cost, for powering single-ended lighting systems such as these. These are probably the latest state of the art in lamp technology in terms of efficiency, quality, reliability, and cost.

We have the ballast in 12-volt and 6-volt versions, a 110 version and 110 AC-DC version, totally at your pleasure. Thank you.

SOLARPAC ENERGY SYSTEMS INC. - MR. MARK R. SANDERSON

Manager
1535 Meyerside Drive
Unit 6
Mississauga, Ontario
L5T 1M9
416 - 674-1616/1833

Mr. Sanderson: Good afternoon. Solarpac Energy Systems is a Canadian company located right here in Mississauga. We've been in business for approximately 1 3/4 years.

What we did in our plan, our strategy, was we bought commercially available equipment from Spire Corporation, an integrated plant capable of one megawatt per year. We started production approximately a year and a half ago

and we've been running steady for about a year in production.

We've been supplying different types of modules for, again, the standard applications that everybody's covered here today.

Outside, you've seen our standard 40-watt module, which is a 36-cell, single-crystal, 4-inch cell, laminated on low-iron, high-tempered glass, standard lamination sandwiches of e.v.a., Tedlar, aluminum frames, standard generic module in the industry.

Aside from that, we also manufacture some other units for different industries; again, standard module, half-cell, 12-volt nominal, amp and a half. This module was recently supplied to communications systems in China for low-power applications.

We've recently developed a new marine module, which comes, again, standard sandwich, only we use a stainless steel back with a clear Tedlar surface, and that module was designed for the marine industry for sailboats or R.V.'s, that kind of application.

It's very durable. It can be mounted; it can be walked on; and it's a 10-watt unit. We retail that for approximately \$249 and, of course, dealer discounts from there -- totally sealed, et cetera.

Specialty modules seem to be where we've done a little bit of advancement. We manufacture different types of specialty modules. This one here is a linear type, 12-volt battery charger, designed, of all things, for shutter openers in skylight applications, where you have a skylight that's inaccessible to opening and closing the shutters. This unit was specifically designed for a company in the States that mounts an aluminum channel up in the window itself.

When the sun comes up, it automatically opens, depending on the cycle you've decided on, opens the curtains when it's light, and at night, it shuts the curtains and keeps heat in. It also comes with a "beaming up, Scottie" type of unit, so you can override it at any time.

That is a standard aluminum module again with a sandwich of e.v.a. and Tedlar on the front -- very durable and

unique.

Recently, we've also developed the same basic module, only in a square version or rectangle, and this one, we're using for data acquisition systems for monitoring of water levels in streams, et cetera, where you don't have a very high power requirement, but you do need a battery charger of sorts. They may sit there for three or four months at a time without any external battery charger. This is where this unit is very unique.

You can mount it right on top of the unit. It's very light, very durable, and we laminate the leads right inside the module, so there's no need for a junction box that you've noticed on some of the other modules.

This also has been recently sold for applications to the military. We have a new unit that incorporates four of these units, so you can have a 12-or 24-volt application, and it comes on a canvas back. It folds up with Velcro ties and mounts on the side of the army personnel. Then, when they're in the field, they just take it off, open it up, and they've got power. It's also an application for the campers and that kind of application.

We have the capability of designing systems. We are primarily a module manufacturer, so that's exactly what we do. We manufacture modules. As a service to our customers, we do design systems. However, we're not a big systems company. We'd rather build panels.

If somebody needs a system designed, no problem. We can supply components, but we do not manufacture any other components. We do not manufacture voltage regulators, inverters, batteries or any of that kind of stuff.

WESTRONIC INC - MR. BRYAN LEACH

Power Systems Manager
4525 Manilla Road S.E.
Calgary, Alberta T2G 4B6
403 - 243-3335

Mr. Leach: Mr. Chairman, ladies and gentleman, thank you very much for inviting us here today. It's a great honour to be here representing Arco. Arco is probably the world's largest solar company with the largest

installed base. We do have experience with systems from as large as 6.5 megawatts down.

At Arco, we manufacture two types of modules now, we're pleased to say. We manufacture the single crystal, which has been the flagship of the Arco line for many years in modules up to fifty-three peak watts, but as of now -- and right now -- large, thin-film modules are being produced. I've seen them. I've touched them. I've had them in my hand. I would have had one here today, if it hadn't been for Canadian Customs, for you to feel and touch as well.

Along with the G-4000 panel, we are also making a full line of small, thin-film modules. The G-25, 1.5 watts at six and twelve volts; the G-50, 2.5 watts at six and twelve volts; the G-100, which we've had for a year now. It's a 5-watt panel and it will be coming out in twelve volts as well as twenty-four volts; and the G-200, which is a 9-watt panel.

Westronic, or Westronic Engineering as it was once known, is now referred to as "Westronic Inc." At the present time, Westronic is the representative for Arco in western Canada. However, at the end of this month, beginning November 1, we will become the representatives for Arco, Canada-wide.

Mechron Energy, who have been representing Arco in eastern Canada, will continue with us and work as an O.E.M. They will continue to work with us in a big way on hybrid systems, which is their specialty.

In order to reach the eastern market from our offices in our base in Calgary and Vancouver, we have brought in a new member of our team, Westronic team, and I'd like to introduce him to you today. Gerry? That's Mr. Gerry Corwin, ladies and gentlemen, who for a number of years was Canadian director of C & D Batteries. He's currently doing work for SAFT Batteries in France and is now working with Westronic.

Westronic Engineering has a complete design capability for you. We can design large systems, hybrid systems, and we offer a full range of services and products to meet your every need. Thank you.

LENBROOK INDUSTRIES LTD - MR. ERIC E. KALMBACH

Manager, Energy Division
633 Granite Court
Pickering, Ontario
L1W 3K1
416 - 831-6333

Mr. Kalmbach: By now, you don't want to hear about another module. Right? This is one of the two systems we supplied recently to CN Telecommunications. Those of you who were here earlier in the week heard the presentation by CN on the engineering of this system.

What I'd like to do is simply introduce Lenbrook Industries as the Canadian photovoltaic systems company.

---SLIDE NO. 176

Some of the work we do. Thank you.

QUESTION & ANSWER PANEL

To complete the presentations of the Seminar a question-and-answer panel had been arranged. Mr. Don Simmonds, who was listed on the original program, had been replaced by Eric Kalmbach, representing Lenbrook Industries, so the panel had two members of the manufacturers and distributors.

There was Dr. Thomas of TPK Solar; Mr. Eric Kalmbach of Lenbrook Industries; and an operator-user, Mr. Brian Losie, to complete the three-member question-and-answer panel. The gentlemen joined the chairman at the front behind their name cards.

In presenting the questions, inquirers were requested to stand, give their name and their affiliation, and ask their question, and the chairman would field it to the appropriate party unless the inquirer had one particular person that he wished to direct his question to.

The following is a verbatim record of the questions and responses.

SPEAKER: I have a question for Mr. Larry McClung. He mentioned earlier that he signed an agreement with the provinces, and I'd like to know what's the scope of participation with the provincial departments of mines and resources in the essential development program of photovoltaics.

MR. ADKINSON: I will direct that question to you, Larry. I think I know the answer. I'll let you give a very brief shot.

MR. McCLUNG: Okay. Memorandums of understanding have been signed with some provinces, not all of them. It is not my field. I'm not too sure what's going on. One thing I do know is that only in one province does it actually cover R and D. In most provinces, the scope is limited to demonstration projects. That province is

Quebec.

MR. ADKINSON: Thank you very much. Do we have a further question? I have one down here.

SPEAKER: I just want to throw on the floor and ask the panel what kind of feeling you have about the photovoltaic industry forming an association to represent its interests.

It seems to me that there's a loose association of maybe about twenty people, but there's no formal representation of your interests, especially to government. It seems that there's no specific program or channel, for instance, to develop programs, although there is in a general way, whereas if you form a specific association, perhaps there might be more money available for developing the manufacturing processes for solar. There seems to be only one manufacturer today in Canada, or maybe two or three.

MR. ADKINSON: Who would like to take a crack at that one? Raye?

DR. THOMAS: I think I got elected because Eric turned the microphone over to me. There is some formal representation at this point with the Conservation of Renewable Energy Industrial Council, the CREIC, so that association is there.

A few years ago, when we tried to get together an association particularly related to photovoltaics, I don't think industry or all the players in photovoltaics at that time were ready. We may still be a little bit early because we're not yet a strong industry in Canada. I think it's worth going into some discussions, though, to see whether we are ready.

MR. ADKINSON: Would any of the other panel members care to make any comments? If not, I would make an observation that there has been some talk in certain areas about initiating such an association. There was a meeting a couple of years ago where we drew up some framework, and some guesstimates as to who might be involved and what-not.

The other parties who were very vitally concerned with that got sidetracked, unfortunately, and I didn't have

the time to spend on it, so it has been lying dormant, but there are now other people who are interested, and if you have an interest in that, I'll be glad to talk to you later on about it. Another question.

SPEAKER: I have a question for the companies. As a user and a fairly isolated user from America, Australia, or whatever, I would like to know what guarantee you give me on your design; i.e., if, after twelve months of operation in Hong Kong, it fails because of bad design, what will you do?

MR. ADKINSON: Eric, do you want to take a crack at that one?

MR. KALMBACH: Well, we haven't supplied to Hong Kong yet. Our policy is that, on the individual contract that we negotiate, we work with the purchaser and we work out the requirements that he has. There are some systems that ask for a five-year guarantee on system performance.

I don't know if you're talking from the point of view of guaranteed power for that period of time or exactly what.

SPEAKER: I'll clarify the situation. I'm talking about a system that is designed by you but it stops working properly, not through reliability failure or through mechanical failure but through system design failure.

As a user, I'm not an expert, so rather than bringing in staff, I might say to you, "I want the system to do this. These are the operating conditions. These are the meteorological data conditions in Hong Kong," and I'll go out on a world-wide request.

MR. KALMBACH: Okay. In that case, we stand behind our system design a hundred percent. I don't think there is any reason not to. I understand the variations that occur in insolation. However, in the systems that we provide, we stand behind them one hundred percent from the design standpoint.

If there is a problem with the system, it's got to be analyzed to see what the problem is. If it's mechanical failure or an act of God or something of that nature, that's a whole different story, but as for system design, yes, we guarantee it.

MR. ADKINSON: Raye, would you care to comment?

DR. THOMAS: I would simply echo Eric's comments. We stand behind our design procedure and the designs that we give. At the point of installation or delivery of any system, guarantees associated with individual components are established, and we stand behind those.

MR. ADKINSON: Thank you. Another question. Doug?

SPEAKER: Doug Hart, Watershed. There was some discussion, and I can't remember which speaker, but about the market crossover when, in looking at a remote power application, there's a size beyond which diesel generating or other commonly used systems become more economical than PV.

I was wondering if there was a consensus or what you feel that size of system is. In other words, what's the market range for PV and what's the market range for something else? Is there a consensus and, if so, I'd be interested in knowing for that crossover point and is it going to change, obviously, when economics change?

MR. ADKINSON: How about, Raye, you taking a crack at that one?

DR. THOMAS: Well, there definitely is a crossover point at this particular point in time and will be crossover points in different locations as you push down the photovoltaics. For example, it's generally accepted now, when you're looking at Africa, you put in the 5-kilowatt diesel system and you put in the photovoltaic system, and there is a crossover point there in performance and cost of those two systems at this stage.

There's a lot less hassle with the photovoltaic system because you're not delivering fuel to them. The projections are that very shortly we will be looking at a 10-kilowatt crossover point.

SPEAKER: So, you'd say five is about the crossover.

DR. THOMAS: Five is about the crossover, and again, it's site-specific. It depends on how far you are from your supply of fuel for diesel, how far you are from your electricity grid, what it costs in putting those in.

MR. ADKINSON: Brian, do you have any comments from a user's point of view on that one?

MR. LOSIE: No, other than to say we're looking at, probably, I would say, two to five kilowatts right now. There comes a point, too, where there's a load-dependence question. What price do you put on reliability of the system or how much insurance do you want?

SPEAKER: But when you talk about five kilowatts, is that your peak power output or is that your lowest constant load? What does that refer to?

DR. THOMAS: We're delivering about one kilowatt constant load.

MR. ADKINSON: I had a question over there.

DR. TOMANTSCHGER: It's not a question. I would just like to comment. I think the slide the gentleman refers to was put up by me, and if you look at the axis, it was really on the remoteness, as it was from near to far, and on the power size, it was from little to big. The simple reason is that it then means you have to answer the questions site-specific.

SPEAKER: You have no numbers on your chart.

DR. TOMANTSCHGER: That's right. In fact, that wasn't done by us. It was a D.O.E. study in the States, and again, if you want to attach real numbers to it, you have to be site-specific.

MR. ADKINSON: I have a question at the back.

SPEAKER: Well, it's not a question. It's just a comment that the present cost of diesel fuel in one place is 63.7 cents. The present cost of diesel fuel in Armstrong Assembly Diesel Plant is 27.8 cents. The difference is one you have to fly, the other you can bring in by truck.

MR. LOSIE: That's per litre.

MR. ADKINSON: That's obviously a very big factor, and this highlights the question of site specificity. If you have a diesel unit that's beside the road, it's completely different.

Do we have another question? Okay. I would like to make one more observation. That is that we have with us at the present time a representative from the Ontario Ministry of Energy, who have also made a significant contribution to the cost of today's Seminar, and I would request that Peter Golobic of OME please stand up and be recognized, and perhaps we can show him how we appreciate his contribution.

APPENDIX A - SPEAKERS PROFILES

APPENDIX A

SPEAKERS PROFILES IN ORDER OF PRESENTATION

DR. RAYE THOMAS - TPK Solar Systems Inc.
----- 36 Bentley Avenue
Nepean, Ontario K2E 6T7
613 - 225-4403

Dr. Raye Thomas, is President of TPK International, formerly TPK Solar Systems Incorporated, from Ottawa, Ontario.

Dr. Thomas has been involved in the Canadian and international photovoltaic community since the early 1970's. He started in industry as manager of a physics of devices group in Northern Electric, now Bell Northern Research, and in 1969 became a professor of electronics at Carleton University in Ottawa.

Subsequently, he has formed his own company, TPK Solar Systems Inc., a company for the production and marketing of PV cells, modules, systems, and hardware. Dr. Thomas and his company have been continuously involved in the PV R and D program sponsored by the National Research Council of Canada and, more recently, that of the Ministry of Energy, Mines, and Resources.

Dr. Thomas is a noted researcher, having presented papers at both the major international PV conferences of the IEEE and the Commission of European Communities. He participates actively in the Canadian PV industry, currently being chairman of the International PV Standards Group in Canada, the Canadian National Committee of the IECTC '82 on photovoltaics.

Additionally, he is a member of the CSA Committee on Photovoltaics Modules, F380, and is a member of the technical Advisory Committee on Photovoltaics to the Energy, Mines, and Resources Energy Program. In June of 1986, his company was awarded the distinction of being named solar company of the year by the Solar Energy

Society of Canada at their annual conference in Winnipeg.

DONALD E. SIMMONDS - Lenbrook Industries Ltd.

633 Granite Court
Pickering, Ontario L1W 3K1
416 - 831-6333

Mr. Donald Simmonds is the General Manager of Lenbrook Industries Limited. Don has been involved in the marketing of photovoltaic modules and systems since 1978 and has well demonstrated his firm's capabilities in the marketing area by acquiring almost a fifty percent share of the Canadian PV market over the past few years. They are considered to be the major marketer of PV in Canada today.

Lenbrook Industries markets Solarex PV modules and systems both in Canada and on the international market and have gained a well earned reputation for reliability. Their experience covers the wide range of sizes and types of PV systems.

SUNNY LEUNG - Canadian Coast Guard (M.A.D.)

Tower A, 6th Floor
Place De Ville
Ottawa, Ontario K1A 0N7
613 - 998-1390

In every industry, there are people who make a particularly significant contribution and impact on that industry by the role that they play in that industry.

Mr. S. Leung is one of these who has been installing photovoltaic systems across Canada for years and, by his promotion of photovoltaic technology within the Canadian Coast Guard for marine navigational aids, has created the major market for PV in Canada in the past few years.

Sunny Leung has established and is in charge of the photovoltaics conversion program for land-based aids throughout Canada. Their PV systems are operational from Sable Island in the east in the Atlantic to Vancouver Island in the west and to Resolute in the north. The

total number of systems now deployed is well over fifteen hundred.

ERIC E. KALMBACH - Lenbrook Industries Ltd.

633 Granite Court
Pickering, Ontario L1W 3K1
416 - 831-6333

Mr. Eric Kalmbach is Manager of the Energy Division of Lenbrook Industries Limited. His work in photovoltaics goes back a number of years in many, many systems.

He has physically installed systems, he has designed systems, he has marketed systems, and he has instructed for several years on PV Technology to the George Brown College energy conversion students.

Eric's day-to-day work brings him into contact with all aspects of system design and system components. He has marketed PV systems both in Canada and in Africa and is very well versed in the problems of system design and the matching of components.

WILLIAM B. REVER - Solarex Corporation

1335 Piccard Drive
Rockville, Maryland 20850
301 - 948-0202

Bill Rever is Product Manager, Systems, for the Solarex Corporation of Rockville Maryland, USA.

In this capacity he has been involved with hundreds of major PV installations, large and small throughout the US, Canada, and around the world. Solarex Corporation supplies not only PV modules but complete systems including their own custom control equipment in many configurations. His experience has been developed and refined in the design of and control selection for these many systems.

DONALD J. ADKINSON - Adkinson & Associates

415 Brian Court
Pickering, Ontario L1W 3H5
416 - 831-2690

Don Adkinson, has been working in photovoltaics since 1979. At that time, he was working with Dr. John Schewchun of McMaster University and worked with the firm Solar Cells Limited in establishing one of the first photovoltaic cell production lines in Canada.

Since 1981, he has been doing R and D and consulting work with various federal, provincial, and private agencies. Recently, he has spent considerable time on standards for PV, both in Canada and in the international field, representing Canada at times on both the Working Group II on modules and Working Group III on PV systems.

His special technical interests in PV at this time focus on performance monitoring of remote systems and the area of energy storage. This is in addition to the continuing role of monitoring the economics of production and technology development.

LARRY McCLUNG - Energy Mines & Resources

460 O'Connor Street, 4th Floor
Ottawa, Ontario K1A 0E4
613 - 995-9447

Larry McClung, is representing Energy, Mines and Resources Canada, who provided the bulk of the financing for the day's Seminar.

Representing EM&R is a new role for Larry, as he joined them only in July of 1986 on an exchange program which puts him into Ottawa for a year from his permanent position with the Ontario Research Foundation in Mississauga.

His title at ORF was Supervisor - Engineering and Physics Test Services. This position brought him into the testing of PV modules and the wonderful world of photovoltaics, and a great depth of PV technical expertise has been developed in Larry through this work.

His current title is now "Technology Co-ordinator, Photovoltaics Solar Energy Development Program, EM&R." He is working at the office on O'Connor Street in Ottawa. He is very conscientious and is working hard at developing appropriate programs for photovoltaics for EM&R.

BRIAN LOSIE - B.C. Telephone
----- 3980 Quadra Street
Victoria, B.C. V8X 1J9
604 - 388-8411

Mr. Brian Losie is an Engineer with B.C. Tel in Victoria, B.C., and works in the power engineering group for the island area.

This work has involved him in several PV applications, including a unique PV-wind-diesel hybrid installation on one of the islands. He has been instrumental in introducing the use of PV to his group, and relates some of that experience.

DR. KLAUS TOMANTSCHGER - Astris Inc.
----- 2480 Donwin Drive
Mississauga, Ontario L5C 1J9
416 - 828-7700

Dr. Tomantschger at the 1984 PV symposium in Ottawa, made an excellent presentation on batteries, particularly for photovoltaics.

At that time, he was with the Institute for Hydrogen studies in Mississauga, and he is now with a company that has taken over their work by the name of Astris Inc.

His special interests are in energy technology, R and D work in primary and secondary batteries, fuel cells, and electric vehicles. His background in energy storage in lead-acid batteries includes work at the K.E. Johnson Environmental and Energy Center. University of Alabama. in Huntsville and post-doctorate work at Case Western

Reserve University in Cleveland, Ohio.

PER DREWES - Ontario Hydro
----- 700 University Avenue
Toronto, Ontario M56 1X6
416 - 592-2928

Per Drewes, is another one of those photovoltaic champions who is really sold on the merits of PV technology. His work with the Ontario Hydro as design specialist, alternative energy systems, has brought to life several major Canadian PV installations.

For several years, one of his first PV projects at Atikokan, Ontario, was the largest in Canada, and now with the recent 10-kilowatt PV grid-connected remote-community system at Big Trout Lake, Ontario, he once again can lay claim to the largest single PV system in Canada.

A vital part of assessing the performance and, hence, economics of a PV system is the performance monitoring system that will provide an accurate picture of what is really happening over the month within the system. This work has been handled by Mr. Drewes on the Ontario Hydro systems, and his presentation reviews these programs and his experiences.

APPENDIX B - INFORMATION SOURCES

PHOTOVOLTAIC APPLICATION SEMINAR OCTOBER 23,1986

Royal York Hotel
Salon A Convention Floor

INFORMATION SOURCES - REPORTS

D.J.ADKINSON

Institutions:

AFME	Agence Francaise pour la Maitrise de l'Energie Val Bonne , France
Brace Research Institute	P.O. Box 900, MacDonald College Ste Anne de Bellevue, Quebec HOX 1C0
EM&R	Energy Mines and Resources Canada, Solar Energy Division, 460 O'Connor St., Ottawa, Ontario. K1A OE4
EPRI	Electric Power Research Institute 3412 Hillview Avenue Palo Alto, California 94304
FSEC	Florida Solar Energy Center 300 State Road 401 Cape Canaveral, Fl. 32920
JRC	ISPRA Establishment 1-21020 Ispra (Varese) Italy
NTIS	National Technical Information Service 5285 Port Royal Road Springfield, VA. 22161
OME	Ontario Ministry of Energy 12th Floor, 56 Wellesley St. West Toronto, Ontario
SERI	Solar Energy Research Institute 1617 Cole Blvd. Golden, CO 80401

Data Bases:

NTIS via CAN/OLE

Publications Section
Canada Institute for Scientific & Technical
Information
National Research Council Canada
Ottawa, Canada K1A 0S2

Periodicals:

Alternative Sources of Energy (ASE)
Alternative Sources of Energy, Inc.
107 S. Central Ave.
Milaca, MN 56353
Energy: The International Journal
The International
Pergamon Press, Maxwell House
Fairview Park, Elmsford, NY 10523

NTIS Energy

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161

Photovoltaics International

Photovoltaics International
2250 North 16th St., Suite 103
Phoenix, AZ 85006

Progressive Builder (Solar Age, REN)
Progressive Builder
Subscription Services
P.O. Box 985, Farmingdale, NY 11737-9685

SOL

The Solar Energy Society of Canada Inc.
Suite 206-135 York Street
Ottawa, Ontario K1N 5T4

Solar Cells

Solar Cells
Elsevier Sequoia, S.A., P.O. Box 851
1001 Lausanne 1, Switzerland or,
Vanderbilt Ave., N.Y., NY 10017

Solar Energy (ISIS)

Solar Energy
Pergamon Press, Maxwell House
Fairview Park, Elmsford, NY 10523

Solar Energy Update (NTIS)

National Technical Information Service
5285 Port Royal Road

Springfield, VA 22161

Proceedings:

CEC PV Solar Energy Conference
IEEE PV Specialists
ISIS
Intelec Conference IEEE
PVSEC Conference
SESCI

Newsletters:

Infosol (EM&R)

Energy Mines & Resources
460 O'Connor Street
Ottawa, Ontario K1A 0E4

PV Insiders Report

Photovoltaic Insider's Report
1011 W. Colorado Blvd.
Dallas, TX 75208

PV (Photovoltaic) News

PV (Photovoltaic) News
PV Energy Systems, Inc.
2401 Childs Lane, Alexandria, VA 22308

Solar Energy Intelligence Report

Solar Energy Intelligence Report
Business Publishers, Inc.
951 Pershing Dr., Silver Spring, MD 20910

Publications:

EM&R-

Contract Reports

Energy Mines & Resources
460 O'Connor Street, Ottawa, Ontario K1A 0E4

Project Reports (Enerdemo)

EPRI-

Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, California 94304

JPL-

Jet Propulsion Laboratory
California Institute of Technology
National Aeronautics and Space Administration
Pasadena, California 91109

NRC-

Contract Registry

National Research Council Canada
Publication Sales and Distribution Office
Ottawa, Ontario K1A 0R6
Contract Reports

NTIS

National Technical Information Service
5285 Port Royal Road, Springfield, VA 22161

OME

Ontario Ministry of Energy
Queen's Park
Toronto, Ontario M7A 2B7

SERI

Solar Energy Research Institute
1617 Cole Blvd., Golden, CO 80401

Manufacturers Literature:

AEG Solar Report AEG Corp, Bldg 3 Suite 130
2222 S. Dobson Rd.,
Mesa, Arizona 85202

Arco Solar News Magazine

Arco Solar Inc.
20554 Plummer Street, Chatsworth, CA 91311

Current (Solarex)

Solarex Corporation
1335 Piccard Drive, Rockville, MD 20850

Design Handbooks:

Monegon NTIS

Photovoltaic Stand-Alone Systems DOE/NASA/0195-1
Preliminary Engineering Design Handbook
NASA CR 165352
National Technical Information Service
5285 Port Royal Road, Springfield, VA 22161

Rauschenbach

Solar Cell Array Design Handbook;
The Principles and Technology of Photovoltaic
Energy Conversion, New York
Van Nostrand Reinhold Company

Standards:

CSA

Canadian Standards Assn., 178 Rexdale Blvd.,
Rexdale, Ontario M9W 1R3 F381, F380

IEC

International Electro-Technical Commission
3, Rue de Varembe, Geneva, Switzerland

ASTM

ASTM Committee on Standards
1916 Race St., Philadelphia. PA 19103

IEEE

IEEE Coordinating Committee for Photovoltaics
345 East 47th Street, New York, N.Y. 10017

APPENDIX C - LIST OF REGISTRANTS

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There are a total of 140 registrations printed.